RECORD OF DECISION

KENNECOTT SOUTH ZONE, OPERABLE UNIT 2

SOUTHWEST JORDAN RIVER VALLEY GROUND WATER PLUMES

U. S. Environmental Protection Agency, Region VIII
Utah Department of Environmental Quality

December 13, 2000

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SOUTHWEST JORDAN RIVER VALLEY GROUND WATER PLUMES

PART 1: DECLARATION

A. Site Name and Location

This Record of Decision covers Operable Unit 2 (Southwest Jordan River Valley Ground Water Plumes) of the Kennecott South Zone Site, proposed for the NPL in 1994. Operable Unit 2 is located in Salt Lake County, Utah, and encompasses the groundwater beneath all or portions of the municipalities of West Jordan, South Jordan, Riverton, Herriman, and portions of unincorporated Salt Lake County. The CERCLIS ID is UTD000826404.

B. Statement of Basis and Purpose

This decision document presents the Selected Remedy for the Kennecott South Zone Operable Unit 2 Site in Salt Lake County, Utah, which was chosen in accordance with the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA), 42 U.S.C. §§ 9601 et. seq. and, to the extent practicable, the National Contingency Plan (NCP), 40 C.F.R. Part 300. This decision is based on the Administrative Record file for this site.

The State of Utah concurs with the Selected Remedy. Their concurrence is based upon the belief that the remedy will benefit the public within the affected area and begin to protect public health and the environment.

C. Assessment of Site

The response action selected in this Record of Decision is necessary to protect the public health or welfare or the environment from actual or threatened releases of hazardous substances and pollutants or contaminants into the environment.

D. Description of Selected Remedy

The selected remedy for Operable Unit 2 (Southwest Jordan River Valley Ground Water Plumes) addresses the ground water contamination for this Kennecott South Zone Site. The surface contamination which originally constituted the principal threat at the site has already been addressed in other removal and remedial actions at OU1 (Bingham Creek), OU3 (Butterfield Creek), OU4 (Large Bingham Reservoir), OU5 (ARCO Tails), OU6 (Lark Tailings and Waste Rock), OU7 (South Jordan Evaporation Ponds), OU10 (Copperton Soils), and OU17 (Bastian Area).

For purposes of clarifying agency authority over the cleanup operations of this action, the agencies plan on using a joint CERCLA and State NRD approach. The cleanup strategy presented within the text of this ROD is concerned primarily with the acid plume in Zone A, under CERCLA authority. EPA maintains the right to intervene in the cleanup of the sulfate plume in Zone B, if it is not addressed sufficiently by the State NRD action. The State of Utah will maintain authority of operations, in both Zones A and B, as they are intended to fulfill the requirements of the NRD settlement. (Please refer to the footnote at the bottom of page 28.)

The performance standards for the selected remedy include achieving the primary drinking water standards in the aquifer of Zone A at the Kennecott property line (as of the date of the signing of this document) for all hazardous substances (i.e. metals). Active remediation (pump and treat) is required to achieve the health-based goal of 1500 ppm for sulfate while monitored natural attenuation is used to achieve the State of Utah primary drinking water standard for sulfate at 500 ppm. The water treated and delivered for municipal use must achieve all drinking water standards of the State of Utah, as a requirement of both the CERCLA action and the Natural Resource Damage (NRD) settlement between the State of Utah and Kennecott Utah Copper Corporation. The performance standard for treatment residuals as measured at or before the end of the tailings pipe is demonstration that the tailings/treatment residuals combination meets the characteristics of non-hazardous waste.

The selected remedy involves treatment and containment of contaminated ground water plumes. The principal threats which caused the ground water contamination have been addressed in previous actions or are contained under provisions of a Utah Ground Water Protection Permit.

The selected remedy contains the following elements:

- Continuation of source control measures as administered through the State of Utah Ground Water Protection Program.

- Prevent human exposure to unacceptably high concentrations of hazardous substances and/or pollutants or contaminants by limiting access to the contaminated ground water. Institutional controls include purchases of land, purchases of water rights , limiting drilling of new wells and increased pumping of nearby old wells as approved (on request) and administered through the State of Utah State Engineer (Division of Water Rights).

- Prevent human exposure to unacceptably high concentrations of hazardous substances and/or pollutants or contaminants through point-of-use management which includes providing in-house treatment units to residents with impacted wells, replacement of their water by hooking the properties up to municipal drinking and/or secondary supplies, and/or modifying their wells to reach uncontaminated waters.

- Contain the acid plume in Zone A by installation of barrier wells at the leading edge of the contamination (1500 ppm sulfate or less), pump and treat the waters to provide a hydraulic barrier to further plume movement while providing treated water for municipal use. The treatment technology for the barrier well waters is reverse osmosis.

- Withdraw the heavily contaminated waters from the core of the acid plume in Zone A and treat these contaminated waters using pretreatment with nanofiltration or equivalent technology, followed by treatment with reverse osmosis to provide drinking quality water for municipal use.

- Monitor the plume to follow the progress of natural attenuation for the portions of the Zone A plume which contain sulfate in excess of the state primary drinking water standard for sulfate (500 ppm sulfate).

- Disposal of treatment concentrates in existing pipeline used to slurry tailings to a tailings impoundment prior to mine closure.

- Development of a post-mine closure plan to handle treatment residuals for use when the mine and mill are no longer operating.

E. Statutory Determinations

The selected remedy is protective of human health and the environment, complies with Federal and State requirements that are applicable or relevant and appropriate to the remedial action, is cost-effective, and utilizes permanent solutions and alternative treatment technologies to the maximum extent practicable.

This remedy also satisfies the statutory preference for treatment as a principal element of the remedy (i.e., reduces the toxicity, mobility, or volume of hazardous substances, pollutants, or contaminants as a principal element through treatment).

Because this remedy will result in hazardous substances, pollutants, or contaminants remaining on-site above levels that allow for unlimited use and unrestricted exposure, a statutory review will be conducted within five years after initiation of remedial action to ensure the remedy is, or will be, protective of human health and the environment.

F. ROD Data Certification Checklist

The following information is included in the Decision Summary section of this Record of Decision. Additional information can be found in the Administrative Record file for this site.

- Chemicals of concern and their respective concentrations, pages 44-45.
- Baseline risk represented by the chemicals of concern, pages 48-49.
- Cleanup levels established for chemicals of concern and the basis for these levels, pages 88-89.
- How source materials constituting principal threats are addressed, page 19.
- Current and reasonable anticipated future land use assumptions and current and potential future beneficial uses of ground water used in the baseline risk assessment and ROD, pages 40-42.
- Potential land and ground water use that will be available at the site as a result of the Selected Remedy, page 42.
- Estimated capital, annual operation and maintenance (O&M), and total present worth costs, discount rate, and the number of years over which the remedy cost estimates are projected, pages 83-87.
- Key factor(s) that led to selecting the remedy (i.e., describe how the Selected Remedy provides the best balance of tradeoffs with respect to the balancing and modifying criteria, highlighting criteria key to the decision), pages 73-79.

G. **Authorizing Signatures**

The following authorized officials at EPA Region VIII and the State of Utah approve the selected remedy as described in this Record of Decision:

Max H. Dodson
Assistant Regional Administrator
Office of Ecosystems Protection and Remediation
U. S. Environmental Protection Agency, Region VIII

12/13/00
Date

Dianne R. Nielson, Ph.D.
Executive Director
Utah Department of Environmental Quality

12/13/00
Date

PART 2: DECISION SUMMARY

A. Site name, Location, and Brief Description

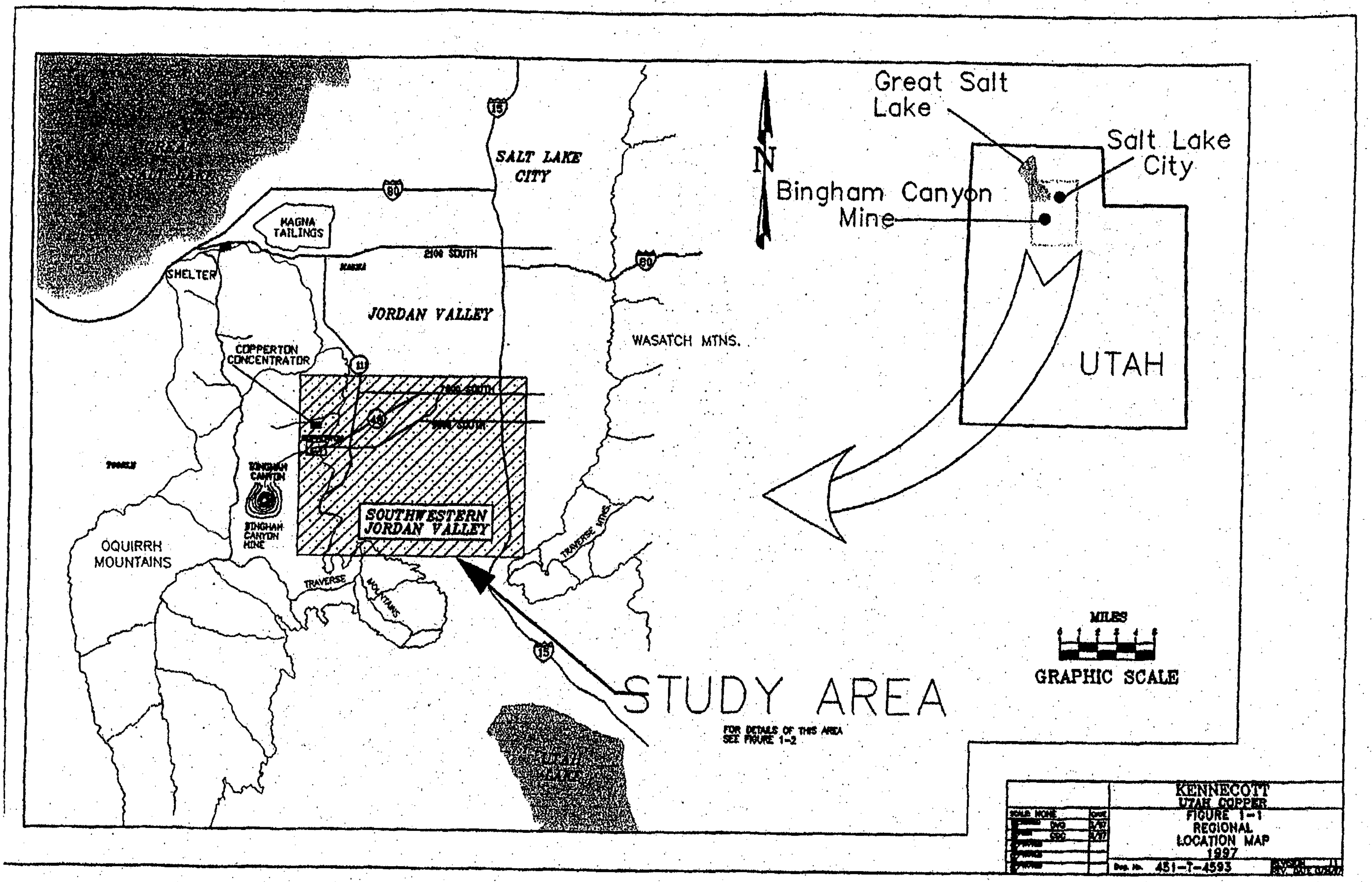
The Kennecott South Zone Site, proposed for the NPL in 1994 (CERCLIS ID UTD000826404), is located in southwestern Salt Lake County, Utah, and covers all or portions of the municipalities of West Jordan, South Jordan, Riverton, Herriman, and unincorporated Salt Lake County. The lead agency for this CERCLA action is the U. S. Environmental Protection Agency (EPA), supported by the State of Utah Department of Environmental Quality (UDEQ). Cleanup funding will be provided by the responsible party. This action addresses ground water problems caused by over a century of mining activities at the site.

The Kennecott South Zone site is located about 10 miles to the southwest of Salt Lake City, Utah. Mining began at the site in 1863 and has continued ever since. Waste management practices of early miners included the dumping of wastes directly into mountain creeks or storing them adjacent to streams. The streams carried the waste down into Salt Lake Valley, which was then largely ranch and farm land. Now suburbs have filled the valley near Salt Lake City. Miners also discovered that additional minerals could be obtained by spraying their waste dumps with water. The wastes contained sulfides which reacted with the water to form sulfuric acid. The acid leached minerals from the waste rock. The miners then collected the metal bearing acidic waters as they emerged at the toe of the waste dumps. Later on, miners realized that the preemptive addition of acidic water would actually increase mineral content of the leachate.

The collection system allowed substantial acid waters, laden with metals and sulfates, to escape and contaminate the ground water. This has rendered a large area of the ground water useless for drinking water, a serious matter in the semi-arid West.

The Kennecott South Zone site is composed of historic mining sites, of surface areas contaminated by mining wastes which migrated from source areas downgradient to cities and towns, and of subsurface areas contaminated by acid leachates from the mining district.

The proposed action at the Kennecott South Zone site involves Operable Unit 02, the ground water operable unit. Surface contamination was addressed by other actions. An area map showing Operable Unit 02 study area and its relationship to nearby mining activities is given in Figure 1 (Figure 1-1, from the Remedial Investigation Report).



Great Salt Lake
Salt Lake City
Bingham Canyon Mine
UTAH
N
SALT LAKE CITY
MAGNA TAILINGS
2100 SOUTH
SHELTER
JORDAN VALLEY
WASATCH MTNS.
COPPERTON CONCENTRATOR
7800 SOUTH
9000 SOUTH
BINGHAM CANYON
BINGHAM CANYON MINE
SOUTHWESTERN JORDAN VALLEY
OQUIRRH MOUNTAINS
TRAVERSE
MOUNTAINS
TRAVERSE MTNS.
STUDY AREA
FOR DETAILS OF THIS AREA SEE FIGURE 1-2
MILES
GRAPHIC SCALE
KENNECOTT UTAH COPPER
FIGURE 1-1
REGIONAL LOCATION MAP
1997
451-7-4593

ROD Figure 1

B. Site History and Enforcement Activities

Mining activities began in the Oquirrh Mountains of Utah in 1863. Early miners recovered mainly gold, silver, lead, and zinc but noticed extensive deposits of low grade copper ore also. The leaching of copper into Bingham Creek was noted as early as 1885 by government geologists. They observed that water which ran or percolated along the copper ore body contained copper sulfate resulting from the oxidation of copper pyrites. At that time, miners made no attempt to recover the very considerable quantity of copper running down the canyon.

Later, in 1903, two mining companies, Utah Copper and Boston Consolidated began experimenting with mining, milling and smelting techniques to exploit the extensive porphyry copper deposits. They developed a mining technique known today as open pit mining in Bingham Canyon and because space was limited for tailings disposal in the canyon, the companies built mills about 13 miles away on the shores of the Great Salt Lake. A smelter was built near the mills.

The open pit mining technique involved blasting the mountain side, later the pit, to obtain the ore, and then send the ore to the mills while dumping the waste rock in nearby gulches. Waste rock also contained minerals, but in concentrations too low to recover economically using milling techniques. It was not long before miners began to notice blue water containing substantial concentrations of copper coming from the toe of the various waste rock dumps in the canyon. Although there were small operations established at the toe of each dump before this, Utah Copper, a predecessor to Kennecott Utah Copper, began a full scale operation to collect the acidic metal bearing waters into a central recovery plant in about 1923. By 1929, Utah Copper staff admitted that they had doubts that the company would ever be able to catch all the copper running to Bingham Creek from their growing waste rock dumps.

Kennecott Utah Copper Corporation [hereafter referred to as "Kennecott]")[1] upgraded their leach water collection system in 1965 when they installed the unlined Large Bingham Reservoir on a former tailings pond at the mouth of Bingham Canyon. Ditches conveyed the leach waters to the reservoir for storage prior to recovery of the copper in their precipitation plant located just upstream of the reservoir. After recovery of the copper, the waters, still acidic, were recycled back to the top of the waste rock dumps. Water balances calculated at the time suggested that water was escaping from the reservoir. Kennecott estimated that the loss of water from the reservoir was 1 million gallons per day. Kennecott used this reservoir from 1965 to 1991, a period of 26 years. During that

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[1] The name "Kennecott" has been used by various entities, some associated with mining activities in Bingham Canyon and some not associated with these activities. " Kennecott" as used in this document refers to Kennecott Utah Copper Corporation and other entities using the name "Kennecott" that were connected with historical activities described in this document.

time, an estimated 9.5 - 16 billion gallons of highly contaminated waters characterized by low pH, high metals, and sulfate, had escaped into the ground water. Kennecott began to monitor the ground water downgradient of the reservoir starting soon after the reservoir was constructed. In 1991, Kennecott retired the old reservoir, cleaned out the sludges and tailings on the bottom, and reconstructed the reservoir. This new reservoir has three basins, is triple-lined and is equipped with a leak detection system.

Kennecott also upgraded canals leading to the reservoir and built cut-off walls across canyon drainages keyed into bedrock to prevent any acid leach waters from traveling underneath the collection system in the alluvial material. Former leakage rates from this source have not been estimated. In the fall of 2000, Kennecott ceased active leaching of their waste rock dumps, although flow from this operation will continue for some time. Even after flow from the active leaching operations has been flushed out, mineral-laden acidic waters will still come from the waste rock dumps but this will be the result of rain or snow falling on the dumps (no excess waters or acids are pumped back to the dumps to increase flows or recoveries).

Several other mining activities caused or contributed to ground water contamination. Along the eastern front of the Oquirrhs are several old mining adits and tunnels, some of which continue to discharge waters. The Mascotte Tunnel was originally driven in 1901 to provide an ore haulage route and drainage outlet from several mines in the Bingham Canyon. Waters infiltrating this tunnel contained so much copper that the mine owners constructed precipitation launders inside the tunnel. This process was enhanced by adding excess water to the dumps above the tunnel. Active leaching ceased about 1931. Before Kennecott began to capture these waters, the waters were used for irrigation. The Bingham Tunnel was originally driven in 1950 to provide an alternative ore haulage route and drainage for the pit. The water was also used for irrigation purposes. The Bingham Tunnel still has some water drainage currently, but the waters are now diverted into the leach water collection system.

Excess waters from Bingham Creek, not known for its pristine waters, were discharged into evaporation ponds built in the valley to the east beginning in the 1930s. These ponds were initially not lined, had gravel bottoms, and the water was not treated. Although the water certainly disappeared, evaporation was not the main mechanism of loss. During the wet years of the 1980s, several of the ponds were lined with clay and the water was neutralized with lime before discharge. The surface wastes in the footprint of the ponds were removed or consolidated and capped in 1994. The ground water plume emanating from this facility is being addressed as part of the separate Natural Resources Damage (NRD) settlement between Kennecott and the State of Utah.

Investigations regarding the ground water contamination began in 1983. A five year study launched in response to the State of Utah Natural Resources Damage Claim started in 1986. A Focused Feasibility Study began in 1992 under CERCLA authority to quickly eliminate alternatives that were not feasible and/or were not cost effective. The Remedial Investigation/Feasibility Study (RI/FS) began in 1995 under provisions of a Memorandum of Understanding (1995) between EPA, the State of Utah, and Kennecott. The NRD settlement was also reached in 1995. The RI/FS document was submitted in 1998, although additional experiments relating to remedial design (RD) are on-going and will be completed during RD. Several treatment technologies were tested using pilot plants beginning in 1996 through the present. A plan to satisfy the provisions of the Natural Resources Damage (NRD) settlement was presented to the State Trustee for Natural Resources in December of 1999. The plan is currently undergoing final revisions.

Significant enforcement actions (involving OU 02) are listed in the following table:

SUMMARY OF OU2 ENFORCEMENT ACTIVITIES

Date	Action	Status
1986	Utah Department of Health files a complaint against Kennecott in Federal Court seeking damages under NRD provisions of CERCLA.	Trial put on hold while the parties collected more information about the extent of contamination. The study, called the Five Year Study, was not formally completed.
1990	Settlement reached between Kennecott and Utah Department of Environmental Quality. A proposed consent decree was lodged with Federal Court.	After substantial negative comment during the public comment period, the Federal District Court rejected the Consent Decree. Appeals to both the Court of Appeals and the Supreme Court were unsuccessful in overturning the rejection.
1991	EPA opens site-wide remediation Consent Decree negotiations.	Negotiations fail in late 1993; there are too many unknowns for both parties.
1994	EPA proposes the Kennecott South Zone for the NPL.	The site is still proposed for the NPL.

Date	Action	Status
1995	After substantial changes and inclusion of water purveyors in the negotiations, a new consent decree for the NRD claims of the state trustee was lodged in Federal Court.	Upon agreement of the three parties, the Consent Decree (CD) was entered by the Court. The CD established a trust fund sufficient to finance a remedial project to supply treated water through the replacement and/or restoration of the lost resource. Kennecott can apply for monies from the trust fund if specific criteria are met. A plan for use of these funds was submitted to the state trustee in late1999.
1995	EPA, Kennecott and UDEQ sign a Memorandum of Understanding which required Kennecott to perform an RI/FS at OU2 (along with other cleanups) in exchange for EPA taking no further action regarding final NPL listing.	The RI/FS for OU2 required by the MOU was submitted by Kennecott in March, 1998.

EPA has approached Kennecott Utah Copper Corporation, a wholly owned subsidiary of Rio Tinto, as a potentially responsible party for OU2. Special Notice letters have not been issued.

C. Community Participation

Community participation for this operable unit began in 1992 when a Technical Review Committee was formed which included scientists and engineers from federal agencies, state agencies, local county and municipal governments, water purveyors, environmentalists, and citizen groups. The members were chosen to represent their communities both to brief them on issues and to bring back concerns to the group. Over the course of the investigations, the committee met over 24 times to review work plans, evaluate progress reports, and discuss issues regarding the treatment alternatives. Future water use needs and land use trends were also discussed during these meetings. A Technical Assistance Grant (TAG) was awarded to a citizen group, Herriman Residents for Responsible Reclamation (HRRR). They were also active participants in the Technical Review Committee.

The Community Participation Plan for the site was outlined in 1991, but was augmented with more detailed plans for each clean up action. For the ground water operable unit, a mailing list of 2000 private and public well owners was developed. Fact sheets, briefings, site tours, and open houses were scheduled periodically throughout the project. Both print and electronic media covered most of the events. One screening exercise was conducted in 1993, and the public were able to voice their concerns early in the study process. This information was used during RI/FS scoping.

The RI/FS reports, a companion Natural Resource Damage proposal, and the CERCLA Proposed Plan were made available to the public on August 1, 2000. These documents are located at the City Recorder's Office in West Jordan City Hall, the offices of Utah Department of Environmental Quality in Salt Lake City, and at the Superfund Records Center in the EPA Region VIII office in Denver. The notice of availability of these documents was advertised in the Salt Lake Tribune and the Deseret News on July 31, 2000. A public comment period was held from August 1, 2000 to August 30, 2000. City councils were briefed and a site tour for elected officials and the media within the Salt Lake Valley was held on July 26, 2000. The problem and proposed plan received extensive media coverage in both local newspapers and on at least one TV station. An open house was held at the offices of Utah Department of Environmental Quality in Salt Lake City. This format gave citizens an opportunity to talk with project principals. The public hearing was held on August 9, 2000, in the City Council Chambers of West Jordan City Hall. EPA's responses to the comments received during this period are included in the Responsiveness Summary, which is a part of this Record of Decision. Concerns of the public included potential impacts of the project on other water rights holders, water uses, and costs to municipal and private water customers.

D. **Scope and role of operable unit or response action:**

When proposed for listing on the NPL, the Kennecott properties were divided into two zones (Kennecott South Zone and Kennecott North Zone) because the two areas were 10 miles apart. However, in reality, the two zones are technically managed as one site because Kennecott continues to mine ore and process minerals utilizing both zones and they are functionally connected via several pipelines, roads, and rail lines. For example, wastes produced by Kennecott's Copperton Concentrator located in the South Zone are slurried to a tailings pond in the North Zone. Waters generated in the North Zone are sent by pipeline to the South Zone for use during the processing of the ore. For this reason, activities in either site can affect operations at both sites. There are 22 Operable Units within the Kennecott sites.

In general, because the overall site is so large, a step-wise site cleanup strategy was implemented by EPA, the State of Utah, and Kennecott, as generally outlined in the site-wide Memorandum of Understanding of 1995. First, CERCLA removal authorities were used to cleanup surface wastes. These actions started in 1991 and are essentially complete in 2000. Second, CERCLA remedial authority as well as the State of Utah NRD authority will be used to cleanup ground water. Finally, the State of Utah permitting authorities, in particular, Ground Water Protection Program Permits, will be used to oversee routine operations and maintenance of the remedies.

The descriptions of operable units related to OU2 and the status of each are given in the table below:

KENNECOTT OPERABLE UNITS (Related to OU2)

OU No.	Description and relationship to OU2	Status
OU1	Surface contamination in Bingham Creek and flood plain. A potential former source of groundwater contamination to OU2.	Cleanups completed by three removal actions, one fund lead, two PRP enforcement actions. Final ROD issued 1998. Two Consent Decrees with the two PRPs were entered in 1999.
OU2	Groundwater plumes in the South Zone 1. Zone A, the acid plume.	RI/FS work completed in 1998. This is the subject of this Record of Decision.

OU No.	Description and relationship to OU2	Status
OU2	Groundwater plumes in the South Zone 2. Zone B, the sulfate plume.	State/Kennecott NRD Consent Decree entered in 1995. Plan submitted to trustee in Dec. 1999. Approval pending.
OU3	Surface contamination in Butterfield Creek and flood plain. A potential source of groundwater contamination to OU2.	Cleanups completed by three removal actions, two PRP enforcement actions, one mixed funding. Final ROD to be issued 2001.
OU4	The Large Bingham Reservoir. This reservoir leaked about 1 MGD into the underlying aquifer. The reservoir was the most serious source of groundwater contamination to OU2 (Zone A).	Old reservoir retired and cleaned under AOC. A new lined reservoir went into service in 1994. Final ROD issued 1998. The site was included in the OU1 Consent Decree of 1999.
OU5	ARCO Tails. Surface contamination produced by non-Kennecott mines in Bingham Canyon. Degree of contribution of groundwater contamination unknown. The site is immediately downgradient from the Large Bingham Reservoir and is above some of the highest concentrations in the groundwater.	Cleanup completed under terms of a UAO about 1997. Final ROD issued 1998. Consent Decree entered for O&M 1999.
OU6	Lark Waste Rock and Tailings. Surface contamination produced by mines and mills near the former town of Lark, Utah. A known source of groundwater contamination to OU2.	Cleanups completed under an AOC, 1994. Final ROD to be issued 2001.
OU7	South Jordan Evaporation Ponds. Surface contamination produced by disposal of mine waters from Bingham Canyon. The ponds were the second major source of groundwater contamination to OU2 (Zone B).	Cleanups completed under an AOC 1995. Final ROD to be issued 2001.
OU10	Copperton Soils.	Contamination not severe enough to warrant action. Final ROD issued 1998.

OU No.	Description and relationship to OU2	Status
OU11	Bingham Canyon. Surface and subsurface contamination. A suspected source of ground water contamination.	With minor exceptions, most of these sites were buried or excavated by later mining operations. No further action needed. Final ROD issued 1998.
OU12	Eastside Collection System. This system was constructed to recover acid leachate from mine dump leaching operations. A source of groundwater contamination.	The system was reconstructed in 1993-1996 under provisions of a state groundwater permit.
OU16	Bingham Canyon Underflow. This is a plume of acidic waters flowing in the alluvium underneath Bingham Creek in Bingham Canyon. A source of groundwater contamination. Also, acidic waters have been found in bedrock underlying Dry Fork, a Bingham Canyon tributary. The significance as a potential source is unknown.	This flow was intercepted through construction of a cutoff wall keyed into bedrock under the provisions of a state groundwater permit. The Dry Fork bedrock aquifer is under investigation by the state ground water program.
OU17	Bastian area. Surface contamination resulting from the use of contaminated irrigation water. The site overlies the groundwater plume emanating from the Large Bingham Reservoir.	Surface contamination was not severe enough to warrant further action except in an historic ditch. Cleanups of the ditch were performed by enforcement actions at OU5 and OU6. Final ROD issued in 1998.
OU15 (North Zone)	Magna Tailings Pond. Tailings generated by two mills are stored in this facility at the North End. The pond is likely to be used as an integral part of the OU2 action while mining operations continue.	Surface discharges from the pond are subject to a UPDES permit. Subsurface discharges are covered under a state groundwater permit.
OU22 (North Zone)	Great Salt Lake. Surface water body receiving discharges from Magna Tailings Pond and other Kennecott waters.	There are no water quality standards for the Great Salt Lake at present. Relevant ecological studies were performed as a part of the North Zone studies.

OU No.	Description and relationship to OU2	Status
OU20	Pine Canyon. Kennecott lands on the west slope of the Oquirrhs are a part of the Kennecott South Zone. However, drainage is to the other side of the mountains and this area is not a source of groundwater contamination at OU2. Non-Kennecott owned land in this area was divested from the Kennecott South Zone to another proposed NPL site, International Smelter.	Kennecott lands in Pine Canyon have been given a No Further Action Status. As a part of the newly proposed areas of Pine Canyon, negotiations with the other party for a RI/FS are underway.

The sequence of cleanups are/were as follows:

KENNECOTT SOUTH ZONE ENVIRONMENTAL CLEANUPS

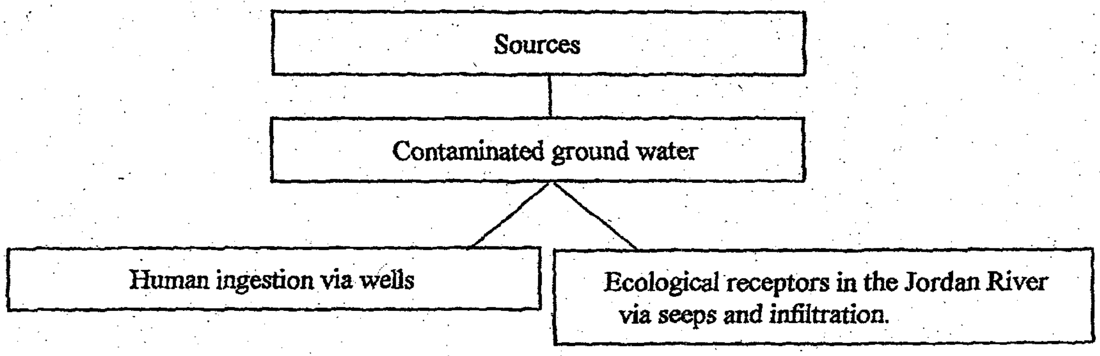
Date (calendar)	Action	Authority	Problem
1991	Bingham Creek residential soils	Time Critical Removal	Flood plain soils were contaminated by lead from upstream mining activity. The land was developed for residential use.
1992-1994	Butterfield Mine Waste Rock	Time Critical Removal	High concentrations of lead in waste rock were left in and adjacent to Butterfield Creek. Materials were eroding into the creek.
1992-1994	Large Bingham Reservoir	Time Critical Removal	Acid leachate leaked from reservoir into ground water.
1993-1994	Bingham Creek sediments	Time Critical Removal	High concentrations of lead in tailings deposited in former creek channel were continuing to erode downstream.
1993-1994	Lark Waste Rock and Tailings	Time Critical Removal	High concentrations of lead and arsenic in tailings were present. In addition, high concentrations of sulfides in waste rock produced acids leaching into the ground water.

Date (calendar)	Action	Authority	Problem
1993-1997	ARCO Tailings	Time Critical Removal	High concentrations of lead, arsenic and sulfides in tailings deposited in and adjacent to Bingham Creek eroded downstream and potentially leached to ground water.
1993-1996	Eastside Collection System, Bingham Tunnel, Mascotte Tunnel	State Ground Water Permit	The collection system is designed to contain acid leachates coming from Bingham Mine waste rock sulfides. It also collects mine drainage from adits.
1994-1995	South Jordan Evaporation Ponds	Time Critical Removal	Waste water settling pond sludges were a known source of ground water contamination via infiltration.
1994	Off-site historic facilities	PA/SI-like investigation	Surface drainages from the mining district were screened for contamination.
1994-2000	On-site historic facilities	PA/SI-like investigation	Individual waste piles were screened and checked for mobility into ground or surface waters.
1995-1997	Bingham Creek residential soils	Time Critical Removal	Final clean up of residential soils contaminated by tailings in the flood plain of Bingham Creek.
1997-2000	Herriman residential soils	Time Critical Removal	Residential soils were contaminated through use of contaminated mine waters for irrigation.
1997-1998	Butterfield Canyon	Time Critical Removal	Tailings left by historic ore mill left in Butterfield Creek were eroding downstream.
1998	Bingham Canyon Underflow	State Ground Water Permit	Contaminated flow in alluvial gravels of Bingham Creek contributed to ground water contamination in the valley.

Date (calendar)	Action	Authority	Problem
1998	Bingham Creek surface waste	Remedial	No Action ROD.
2000	South Zone Ground Water	Remedial	The focus of this ROD, RD/RA begins 2001.
2001	Butterfield-Lark surface waste	Remedial	Institutional Controls only ROD is anticipated in 2001.
2001-2002	Precipitation Plant	Remedial	Decommission, demolish, and clean soils surrounding former processing plant for leach water. The plant was closed in 2000.
2005	Site Wide	Remedial	Construction Complete.

E. Site characteristics

1. Conceptual Site Model and Description:



Sources: The major source of the contaminated ground water in Zone A was leakage from the Large Bingham Reservoir. Other sources included acid leachate leaking or escaping capture from the Eastside Collection System (includes Butterfield Creek and Bingham Creek underflow), and historic tunnels at Lark. The sources of contaminated ground water in Zone B were leakage from the South Jordan Evaporation Ponds and several non-mining sources. The mining-related sources have all been addressed by previous response actions.

Contaminated Ground water: For administrative purposes the ground water plumes have been divided into two zones. The acid plume (sometimes referred to as the CERCLA plume) in Zone A contains low pH waters and high metals with sulfates exceeding the CERCLA recommended risk based action level of 1500 ppm. The sulfate plume (sometimes referred to as the NRD plume) in Zone B contains waters exceeding the Secondary Drinking Water Standard for sulfate of 250 ppm. For the purposes of this ROD, the plumes will be described as Zone A for the acid plume or Zone B for the sulfate plume. Although the waters in Zone B do not rise to the level of a health risk, they are not useable for public drinking water supplies without blending or treatment. The Zone A acid plume originates largely from the Large Bingham Reservoir. The sulfate plume originates from the South Jordan Evaporation Ponds in Zone B and the migration of sulfate-laden ground water from Zone A. (See Part1, Declaration, for the division of authorities used in the combined CERCLA-NRD action.)

Human ingestion: Ingestion of contaminated well water is the major pathway of potential human exposure for people in the affected area. There are some other minor concerns which include using the water for irrigation and stock watering purposes. The exposure points are scattered throughout the aquifer at private and municipal wells.

Ecological receptors: The ground water in this area flows from the mountain recharge areas to the Jordan River which is the point of discharge and exposure point to aquatic organisms living in the river. The Jordan River near the affected area is classified as a cold-water fishery. The discharge of treatment brines is a potential problem for the Great Salt Lake ecology.

2. *Overview of the site:*

Size of the site: The contaminated ground water underlies a 72 square mile area. The core of the acid plume is about 2 square miles in size.

Geographical and topographical information: The site is located in the Southwest portion of the Jordan River Valley. On the western edge of the site is the Oquirrh Mountain Range which has been an important mining area in the State of Utah since 1863. Several creeks begin in these mountains and historically flowed toward the east and the Jordan River. These creeks include Bingham Creek, Midas Creek, and Butterfield Creek. Today, because virtually all the water coming from the mountains is captured for use as industrial or irrigation waters, the creeks do not flow except during rain events. Each of these creeks has an associated flood plain, but the size of the current flood plain is much smaller today than historically due to the impoundment of these waters. Buried channels of these creeks often serve as preferential flow pathways for subsurface waters.

Because of the availability of water during historic times, several farming communities were founded along the creeks. With the growth of urban development in Salt Lake Valley, most of these communities are now suburban in character and are part of the Salt Lake City Metropolitan area. The Cities of West Jordan, South Jordan, and Riverton, and the Town of Herriman overlay the contaminated ground water.

Except in and near the mountains, the valley floor is relatively flat, gently sloping toward the Jordan River. There are some wetlands adjacent to the Jordan River at the eastern boundary of the site. The wetlands are fed by seeps originating from the shallow aquifer. In addition, several of the cities along the Jordan River are considering wetland restoration projects in this area.

3. *Surface and subsurface features*:

Proceeding from west to east, surface features in the Oquirrh Mountains and foothills include mining operations of the Kennecott Utah Copper Corporation and remnants from historic mining activities. The facilities which were implicated in ground water contamination are described later. Adjacent to the mountains is a band of agricultural lands either owned by Kennecott and leased to farmers or privately held. Over the eastern edge of the site are three cities. In addition, transecting the site from north to south are several irrigation canals which transport Utah Lake water and Jordan River water inland for use by farmers and residents for irrigation of lawns, crops, and gardens. Subsurface features are largely associated with infrastructure of the cities, such as sewers, water lines, gas station tanks, etc. The overlying municipalities have associated residential and commercial zones, some of which have private wells. Some of the municipalities have municipal or private water company well fields for the production of water.

Areas of archaeological or historical importance: There are numerous areas of historical significance including the mining district itself and early structures built by the Pioneers who settled here beginning in 1847. Areas of historical significance would not be affected by the proposed action.

4. *Sampling strategy*:

Samples of ground water were collected in order to determine the lateral and vertical extent of the contamination, monitor plume movement over time, provide data needed to calibrate the ground water model, characterize aquifer materials, determine if private well owners need immediate relief, and provide early warnings should municipal water supplies be threatened. Samples of ground water were also used in studies to assess potential impacts to various water uses such as irrigation and industrial waters. Ground water was also used in pilot testing for elements of the alternative remedies and the characterization of potential waste streams. Routine monitoring of some wells is required as a part of the state ground water permit to determine if leakage from operating facilities is occurring. Many of the wells were used in a multivariate statistical approach for the determination of background concentrations. Some were used for isotopic tracing and age dating purposes.

All private and municipal wells were monitored at least once. Wells close to the sources were monitored quarterly and others less frequently. The historic database on ground water quality dates back to the early 1960s, but most of the wells were installed in the late 1980's. Several of the recently installed wells in the heart of the plume have completions at multiple depths so that water from different layers in the aquifer can be sampled from one well. (See RI/FS for further details.)

5. *Description of known or suspected sources of contamination*:

The major source of contamination to the ground water in Zone A was the Large Bingham Reservoir, formerly used to collect leach waters and runoff from the Bingham Canyon open pit mine. It also contained water associated with waste rock dump leachate, and flows from Bingham Creek.

The former Large Bingham Reservoir was constructed in 1965, and retired from service in 1991. It is suspected that during the entire history of the operation of this reservoir, leakage rates to the underlying aquifer averaged about 1180 gpm (approximately 1 million gallons per day). The waters in the reservoir were characterized by low pH, high metals, and very high sulfate, all characteristic of acid rock drainage. This area was designated OU4 of the Kennecott South Zone site. The sludges, tailings, and underlying soils were removed in 1992-1993 and a new lined reservoir with three basins was constructed in 1994-1995. The cleanup was performed under CERCLA removal authorities and provisions of a state ground water permit.

Another source of ground water contamination in Zone A was Bingham Canyon alluvial flow, sometimes referred to as Bingham Creek underflow. In Bingham Canyon, the flow of Bingham Creek is only partially at the surface. A substantial flow travels in the alluvium at the interface between the bedrock and the channel alluvium. These waters are also characterized by low pH, high metals, and high sulfate. Recent data suggests that this flow discharged into the principal aquifer at a rate of at least 300 gpm. Kennecott installed some wells to intercept this flow in 1989 (not entirely successful), and in 1996 built a cutoff wall at the mouth of the canyon keyed into bedrock to capture the total flow. The degree to which flow in the bedrock goes underneath the cutoff wall is unknown. This work was performed under provisions of a state ground water permit. It is OU 16 of the Kennecott South Zone.

Another source of ground water contamination in Zone A was the Cemetery Pond, located next to the Copperton Cemetery. It was built in 1984 and used until 1987. It served as a lime treatment basin for treatment of acid waters from the Bingham Canyon Mine and North Ore Shoot. It had a gravel bottom and leaked at an estimated rate of 2000 gpm. The water was generally alkaline, but had elevated sulfates and TDS. The bottom sediments contained elevated arsenic. This pond was retired from service in 1992 and the sediments were cleaned out. The area was included in the Final ROD for Bingham Creek in 1998.

Another source of ground water contamination in Zone A includes the waste rock dumps and Eastside Leachate Collection System. Early miners noticed that acidic copper-laden waters were produced when rain water came in contact with sulfides incorporated within the waste rock dumps. The sulfides were oxidized to form sulfuric acid and the acid then leached metals out of the waste rock. (Note: Waste rock does have some metal content but not enough to economically process.) Miners began to collect the acidic metal laden waters and process them to recover the metals. Kennecott enhanced this process by actively spraying the tops of the dumps with recycled water starting in 1942. A system of canals were built to collect the water at the toe of the dumps as the metal rich water emerged. Initial activity was centered largely in Bingham Canyon. Excess waters were sent to the South Jordan Evaporation Ponds. The collection system was expanded in 1965 so that leaching operations could be extended to the Eastside Dumps. The system was upgraded in around 1982 using ponds and concrete ditches. Beginning in 1991, the collection system was again upgraded to install cutoff walls at gulches keyed into bedrock in order to capture any underflow through the alluvium. The volume of acid waters escaping or eluding the capture system have not been estimated. Preliminary data suggest that in certain areas (Dry Fork and Bingham Canyon) acid leachate has penetrated into the bedrock aquifer. This potential source of contamination is currently under investigation as part of the Utah Ground Water Protection Program.

A known source of contamination in Zone A was acidic discharges from historic mine tunnels located along the east side of the Oquirrh Mountains. An area of poor quality groundwater is located downgradient of the portals of two tunnels in the old Town of Lark. The Mascotte Tunnel was originally constructed in 1902-3 to access the ore body in the Oquirrh Mountains. It was also used as an outfall for waters infiltrating into the mines. Water was pumped from the various shafts into the tunnel. At one time, the waters contained enough metals that the miners set up metals recovery launders within the tunnel itself. The water was discharged into the area of the Lark Tailings dump until 1942. At that time a pond was constructed (Mascotte Pond) and the water was used for irrigation. During active pumping of the shafts serviced by the tunnel, flow rates were 1000 - 3000 gpm. After 1952, discharges from Mascotte Tunnel were intercepted by the new Bingham Tunnel nearby. Bingham Tunnel water, when it was not used for irrigation in Herriman, was discharged to Midas Creek until 1988. The current flow is 600 - 1000 gpm and is now routed into the Eastside Leachate Collection System described earlier.

A potential source of ground water contamination in Zone A was the Small Bingham Reservoir adjacent to the Large Bingham Reservoir, described earlier. It was built in 1965, was retired from service in 1988, and was reconstructed in 1990 with HDPE linings. It held waters similar in composition as the Large Bingham Reservoir. Since it had only 4% of the capacity of the Large Bingham Reservoir its leakage rate was probably small in comparison. The reservoir was addressed in 1990 and was included in the 1998 ROD for Bingham Creek

Another potential source of ground water contamination for Zone A located in the Lark area was the Lark Tailings and Waste Rock site. This area was used as a disposal site for tailings and wastes of various mining operations in the area. The waste rock had the potential to generate acid waters. There has been no estimate of the flow rate. In 1993, the tailings with high metals were relocated to the Bluewater Repository and the waste rock was relocated to Kennecott's main waste rock dumps (behind the Eastside Collection System). There is one seep in the Lark Tailings area which had moderately contaminated water. The seep is used for experimentation using artificial wetlands for treatment of high sulfate waters. The Lark area is OU 06 of the Kennecott South Zone. Cleanup was performed by Kennecott using CERCLA removal authorities. A Final ROD for this site has not been issued.

Another potential source of contaminated water in the vicinity of Bingham Creek area was the ARCO Tailings (also called Copperton Tailings and Anaconda Tailings). This series of tailings impoundments were constructed around 1910 to capture tailings from mining and milling operations of the Utah Apex operations located in Bingham Canyon. Tailwaters were used by local farmers for irrigation purposes. The impoundments were located immediately downgradient of Kennecott's Large Bingham Reservoir. The tailings did have the potential to generate acid waters, but it is unknown how much acid waters made it to the underlying aquifer. This area was capped by ARCO under provisions of a removal Unilateral Order in 1993-1997. The Final ROD was issued in 1998. The area is OU 05 of the Kennecott South Zone.

The major source of ground water contamination in Zone B was the South Jordan Evaporation Ponds. These ponds were used intermittently from 1936 to 1986 to dispose of excess water from Bingham Canyon. The waters were acidic and high in sulfate. The original ponds were not lined and had sand and gravel bottoms. During the later period of operations, some of the ponds were lined and waters were treated with lime before disposal. Infiltration rates varied depending on the amount of water in the ponds. Estimates of 150 gpm to 1110 gpm have been proposed. The ponds were retired from service in 1986. The ditches leading to the ponds were cleaned as a part of the Bingham Creek removal action in 1992 and the sludges remaining in the ponds were addressed as part of the South Jordan Evaporation Pond Removal Action during the 1994-1997 time frame. This area is OU 07 of the Kennecott South Zone.

Because the mining activities in the area have been ongoing since 1863 and continue today, the sources of ground water contamination from these activities were numerous. An intensive effort to contain or remove these sources was the first order of business at the Kennecott South Zone site. Currently, with the potential exception of Dry Fork bedrock contamination, all of the above known and potential sources associated with mining activities have been contained or removed. There are other non-mining related sources that impact ground water. Some of these are natural such as natural leaching of mineralized areas in the mountains and geothermal activity. Others are man-made such as irrigation water, canals and runoff from urban areas. For the purposes of this action, the non-mining sources are considered to be part of the "background".

6. *Types of contamination and the affected media:*

Types and characteristic of Chemicals of Concern: Because the ground water was contaminated through the release of acidic metal-laden waters emanating from mining activities, the chemicals of concern are largely inorganic chemicals, particularly metals and sulfates. The metals are mobile and toxic; some are carcinogenic, and others non-carcinogenic. Mobility of the metals and sulfates is enhanced in the presence of low pH waters near the sources. For operational reasons the ground water has been divided into two plume areas, the acid plume (the subject of this Record of Decision) and the sulfate plume (being addressed in a separate Natural Resources Damages settlement). See also Part 1, Declaration, for a discussion of the authorities and their role in the combined response.

Quantity/volume of waste: The Remedial Investigation estimated the volume of contamination using different criteria. A summary table follows:

VOLUME OF CONTAMINATED GROUND WATER (Zone A)

Contamination range	Volume (acre-feet)
Sulfate concentrations > 1500 mg/l	171,000
Bingham Reservoir Area	168,000
Remaining areas	3,700
Sulfate concentrations> 20,000 mg/l	19,000
pH < 4.5	54,000

Concentrations of Chemicals of Concern: The chemicals of concern are different for the two plumes. For the acid plume in Zone A, an example of the concentrations of the chemicals of concern in the ground waters close to the major source in comparison with primary and secondary drinking water standards are given in the following table (information from the RI/FS):

CONCENTRATIONS OF CHEMICALS OF CONCERN
(Downgradient of the Large Bingham Reservoir, all data)

Chemicals of concern	Drinking water standard (primary or secondary) mg/l	Max. concentration in acid plume (downgradient of Large Bingham Res.)	Ratio (acid plume/standard)
Arsenic	0.05	4.1	82
Barium	2	0.9	0.45
Cadmium	0.005	9.34	1868
Chromium	0.1	0.99	9.9
Copper	1.3 (action level)	192	147
Fluoride	4	16.2	4.05
Lead	0.015 (action level)	0.85	56.6
Nitrate	10	4.5	0.45
Selenium	0.05	0.9	18
Nickel	0.1 (Utah)	850	8500
Aluminum	0.05 - 0.2(secondary)	4690	23450 - 93800
Chloride	250(secondary)	539	2.1
Copper	1.0 (secondary)	192	192
Fluoride	2.0 (secondary)	16.2	8.1
Iron	0.3 (secondary)	1222	4073
Manganese	0.05 (secondary)	1100	22000
pH	6.5 - 8.5 (pH units)	2.6 (minimum pH)	7943
Silver	0.10(secondary)	0.24	2.4
Sulfate	250 (secondary)	59,000	236
TDS	500 (secondary)	77,574	155
Zinc	5 (secondary)	544	109

RCRA hazardous wastes: EPA is not making any determination on the Bevill Exempt status for the ground water or treatment residuals at this time. (See footnote at end of State ARARs discussion in Appendix A.

7. *Description of the location of contamination and known or potential routes of migration.*

Lateral and vertical extent of contamination: The lateral extent of contamination along with the known sources is shown on Figure 2 (Figure 4.4 of the Remedial Investigation Report). As mentioned previously, there are two main plumes of ground water contamination. The western plume, sometimes also known as the acid plume or Zone A, is where the highest concentrations of contaminants are found and is the subject of this Record of Decision. The area exceeding one or more primary drinking water standards measures about 5 miles by 5 miles. Within the acid plume, there is a core area immediately downgradient of the Large Bingham Reservoir, and minor fingers of contamination originating near the toe of the waste rock dumps in various gulches including Bluewater I Gulch, Bluewater II Gulch, Bluewater Gulch, Midas Gulch, Keystone Gulch (near the Bingham Tunnel portal), North Copper Gulch, Copper Gulch, Yosemite Gulch, and two gulches in Butterfield Canyon.

The depth to ground water ranges from 50 to 400 feet in the most heavily contaminated core area near the Bingham Reservoir. The contamination in the core extends to the bottom of the aquifer. The contamination in Zone A persists in the top 100 - 600 feet of the principal aquifer on average. In the Lark area (the finger of contamination starting near the Bingham Tunnel) the contamination is in the top 50 to 150 feet of the principal aquifer.

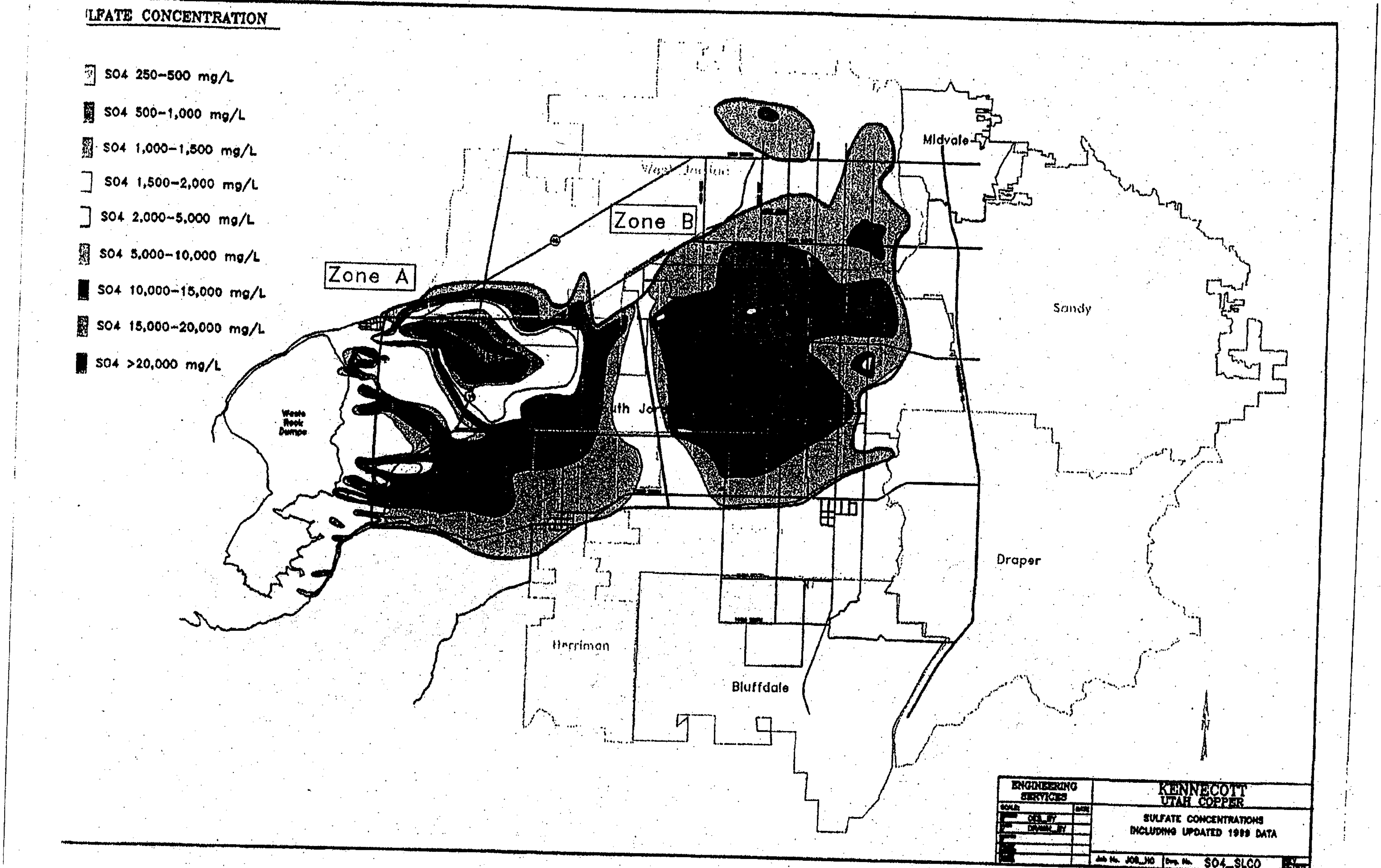
Current and future locations: The location of the contamination relative to the sources is shown on Figure 2 (Figure 4-4, reprinted from the Remedial Investigation Report). This figure demonstrates sulfate concentrations. In general, the low pH and high metal concentrations are located in the areas designated by reds and orange on this figure. This portion is the core of Zone A. Most of this plume originated from leakage from the Large Bingham Reservoir. Minor sources were leaks from the dumps (shown as fingers of contamination coming down the western gulches). The plume in Zone A is the subject of both this Record of Decision and the Natural Resources Damages action.

In Zone B, the plume to the east is characterized by lower sulfate concentrations with only a few hot spots of metals and low pH. This plume is known in various documents as the sulfate plume, the NRD plume and Zone B. The major source of sulfate contamination in this area is the South Jordan Evaporation Ponds. It is this area which is being addressed primarily using the Natural Resources Damage Settlement.[2]

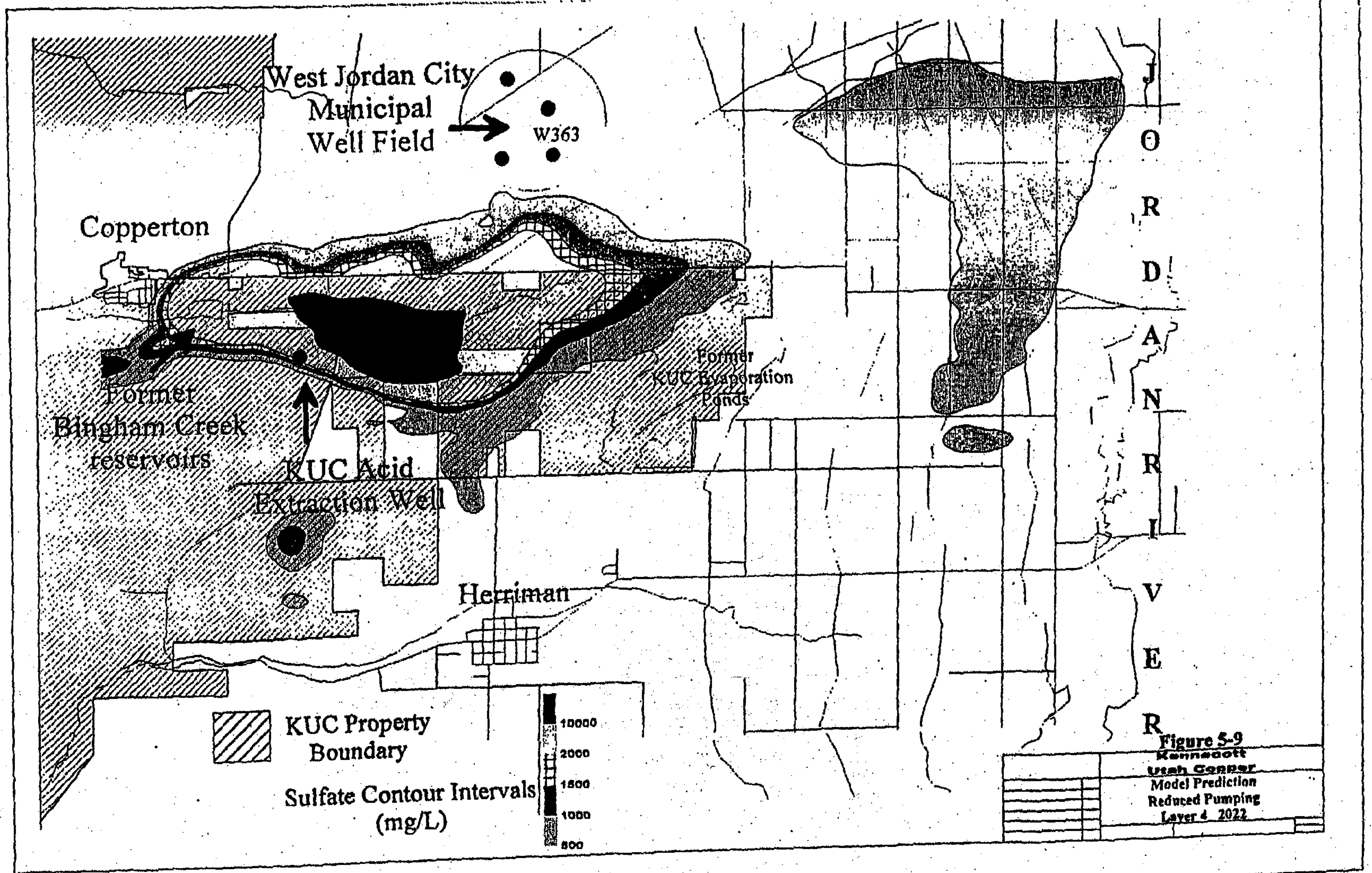
Both of these plumes were modeled in the RI/FS and the NRD Settlement proposal to predict the migration of the plumes under different scenarios. An example of one such scenario is given in Figures 3, 4, and 5 (Figures 5-9, 5-10 and 5-11 from the Remedial Investigation Report). These figures give the migration predictions assuming no action and illustrates the movement of sulfate in 25 years, 50 years, and 150 years. In general, the plumes continue to move to the east, away from the mountains toward the Jordan River.

The model results point out three areas of concern to the agencies. (1) After 50 years, the acid plume has reached the West Jordan municipal well field, the major source of water for the city. (2) After 150 years, high concentrations of sulfate begin to approach the flood plain of the Jordan River presenting a threat to the aquatic ecology of the river. (3) The highest concentrations of contaminants in the plume will move off existing Kennecott property after 50 years.

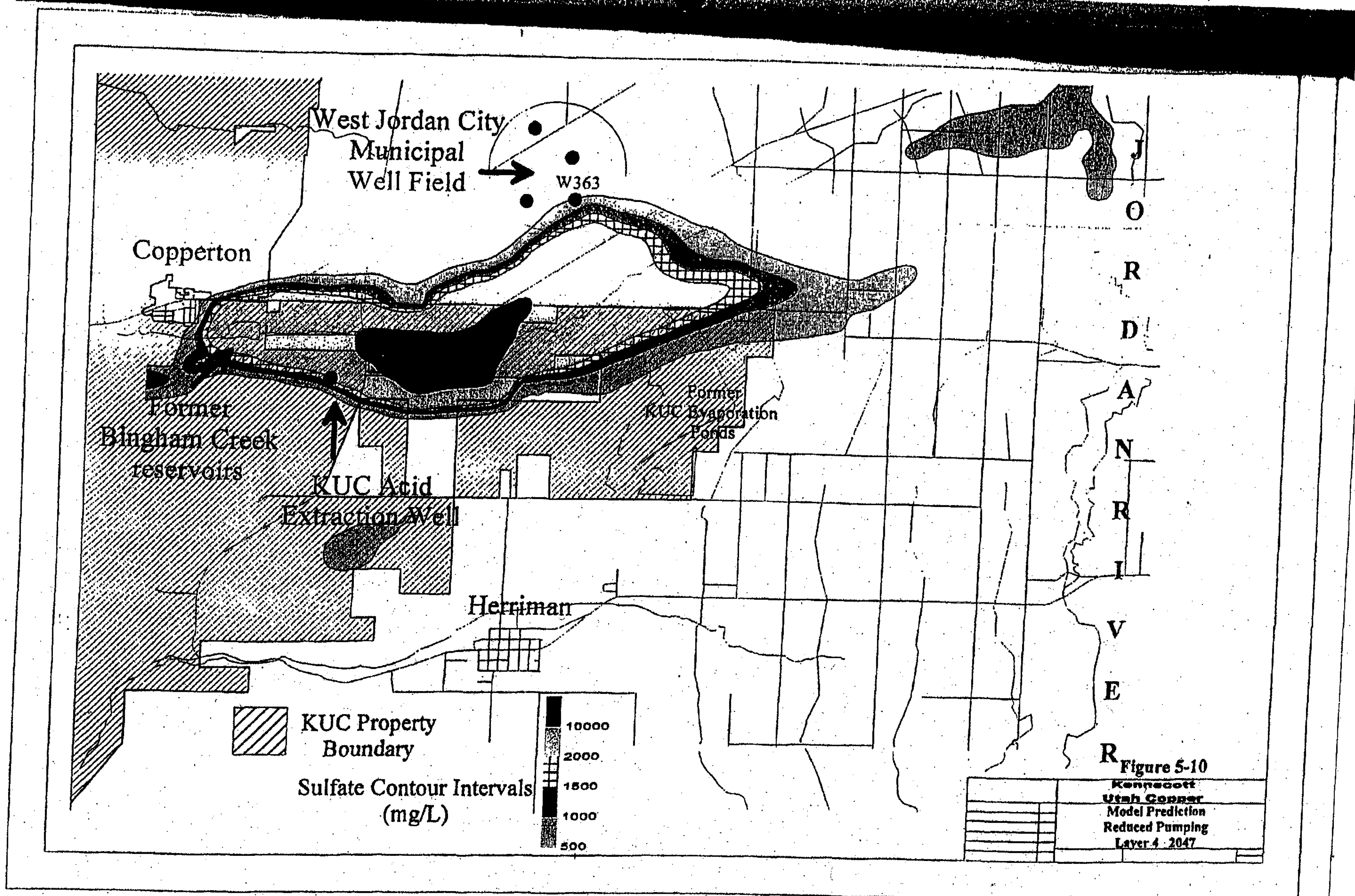
[2]EPA reserves the right to address contamination in Zone B if the NRD settlement is not carried out in a manner acceptable to EPA or if new information indicates that action by EPA is warranted. Likewise, the state of Utah reserves the right to use the NRD settlement provisions should CERCLA RD/RA activities in Zone A be insufficient.


LFATE CONCENTRATION
SO4 250-500 mg/L
SO4 500-1,000 mg/L
SO4 1,000-1,500 mg/L
SO4 1,500-2,000 mg/L
SO4 2,000-5,000 mg/L
SO4 5,000-10,000 mg/L
SO4 10,000-15,000 mg/L
SO4 15,000-20,000 mg/L
SO4 >20,000 mg/L
Zone A
Zone B
Midvale
Sandy
Waste Rock Dumps
Draper
Herriman
Bluffdale
ENGINEERING SERVICES
KENNECOTT UTAH COPPER
SULFATE CONCENTRATIONS INCLUDING UPDATED 1989 DATA
SO4_SLCO

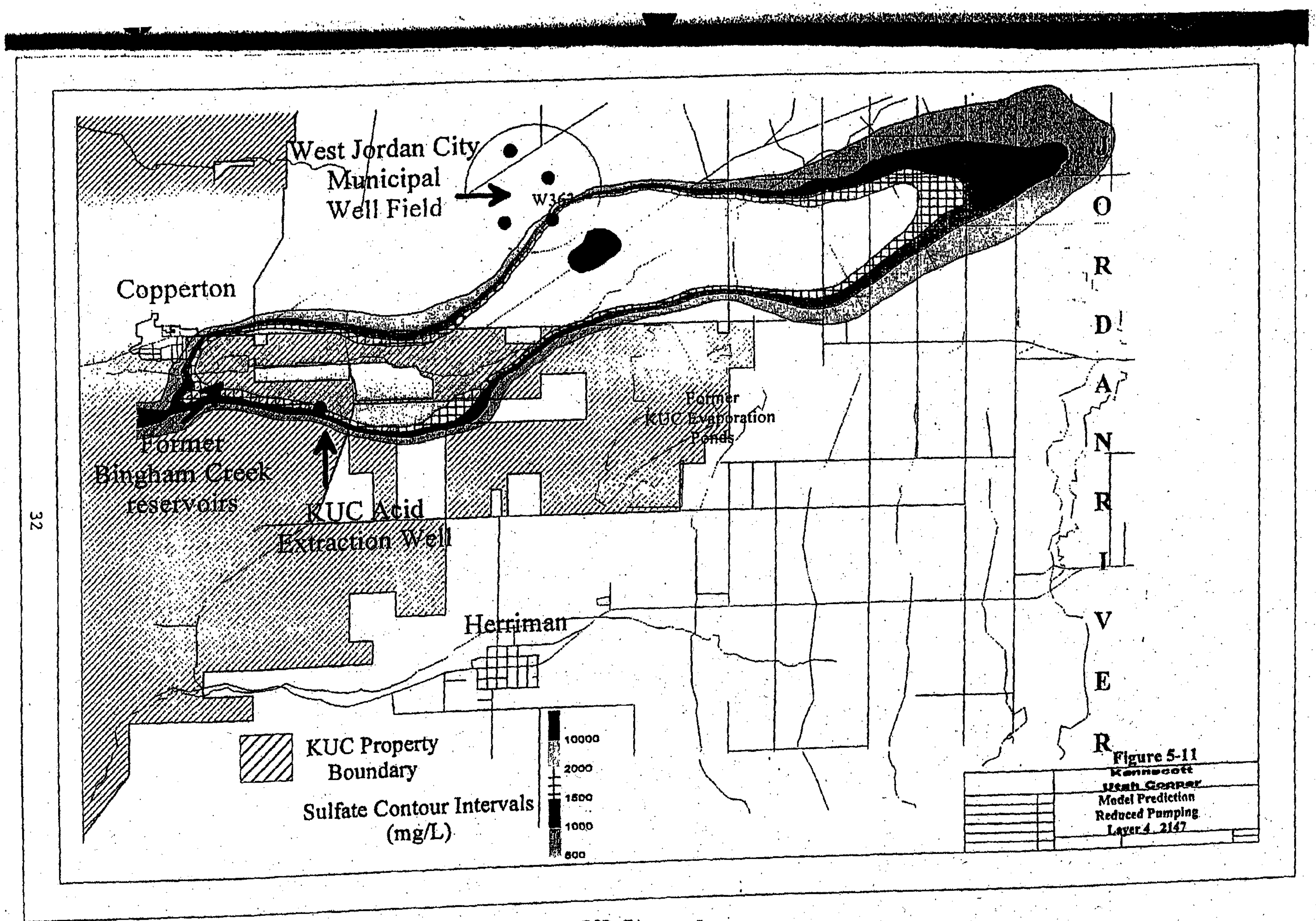
ROD Figure 2


West Jordan City
Municipal
Well Field
W363
Copperton
Former
Bingham Creek
reservoirs
KUC Acid
Extraction Well
Former
KUC Evaporation
Ponds
Herriman
J
O
R
D
A
N
R
I
V
E
R
KUC Property
Boundary
Sulfate Contour Intervals
(mg/L)
10000
2000
1500
1000
800
Figure 5-9
Kennecott
Utah Copper
Model Prediction
Reduced Pumping
Layer 4 2022

ROD Figure 3


West Jordan City
Municipal
Well Field
W363
Copperton
Former
Bingham Creek
reservoirs
KUC Acid
Extraction Well
Former
KUC Evaporation
Ponds
Herriman
JORDAN RIVER
KUC Property
Boundary
Sulfate Contour Intervals
(mg/L)
10000
2000
1500
1000
500
Figure 5-10
Kennecott
Utah Copper
Model Prediction
Reduced Pumping
Layer 4 2047

ROD Figure 4



West Jordan City
Municipal
Well Field
W363
Copperton
Former
Bingham Creek
reservoirs
KUC Acid
Extraction Well
Former
KUC Evaporation
Ponds
JORDAN RIVER
Herriman
KUC Property
Boundary
Sulfate Contour Intervals
(mg/L)
10000
2000
1500
1000
500
Figure 5-11
Kennecott
Utah Copper
Model Prediction
Reduced Pumping
Layer 4 2147

ROD Figure 5

Current and potential future surface and subsurface routes of human or environmental exposure: As illustrated previously, modeling of the ground water plumes suggest that the contamination will continue to migrate eastward toward the Jordan River if nothing is done to contain or treat the plumes. The acid plume may also migrate northward toward the West Jordan City municipal well field depending on pumping rates by West Jordan. This could create a potential health threat to the West Jordan City residents or cause abandonment of the well field. Though Riverton City has a municipal well field as well, the main source of impact to this system would be from the sulfate plume in Zone B, the focus of the Utah NRD action.

A well inventory was conducted during the RI/FS. The inventory located 1688 wells. Of these wells 523 were monitoring wells, 559 were in use, and 606 were not in use, damaged or missing. Of the 559 wells in use, 347 were used for culinary purposes (either solely or in conjunction with other uses), and 212 were used for other purposes such as stock watering, irrigation, commercial. Although most of these well owners now have access to municipal water supplies, many continue to use their wells for lawns and agricultural uses. The well inventory represents information for both Zones A and B. Future exposure is possible if the plumes are not contained.

Some preliminary ecological risk calculations were performed to assess ecological risk. The two places where the plumes could discharge to surface water bodies are the Jordan River and the Great Salt Lake. In both cases, the current sulfate inputs are minor in comparison to the sulfate already present in these water bodies. Note that this describes the current condition, not the future threat which modeling suggests might occur in 150 years (see later discussion). At that time, sulfate loading from ground water could have a significant impact on the river.

Likelihood for migration for Chemicals of Concern: The agencies are certain that the contaminants of interest will continue to move eastward if nothing is done to contain or treat the plume in Zone A. The leading edge of the acid plume has already moved 5 miles from its original source in the last 35 years. Although the pH will be neutralized and the metals removed into the solid phases of the aquifer, sulfate is totally soluble in water up to about 2000 ppm. As the water moves around 500 feet/year, the sulfate will move with it. The movement of metals is much slower because of the neutralization-precipitation chemical reactions with the alluvium materials.

Human and ecological populations that could be affected: Although current exposures are limited to the public with private drinking water wells, the affected area is located in a semi-arid climate where water resource availability is a serious issue to all residents in the area. In addition to the private well owners, there are two municipal well fields just outside the area of the contamination. There is valid concern that depending on the pumping scenarios, contaminated water could be drawn in the direction of the municipal fields limiting their future use as a water supply. Most of the other residents in this area are served by public water suppliers which import the water from surface reservoirs in the mountains. The ground water underlying these cities is a valuable resource which has not yet been utilized by the municipal water purveyors due to the expense of dealing with the contamination. Thus the entire population of this area is affected either directly by ingestion of the water or indirectly by the extra cost of providing water from outside the area. The population for both zones was estimated to be 117,059 in 1997 and is projected to grow to 286,905 by 2020. Use of the ground water resources of the affected area is desired by all the communities in the area.

Ecological receptors of untreated waters from the plumes are limited to the aquatic species in the Jordan River. This is not a major concern currently because the water quality of the Jordan River as it leaves its headwaters in Utah Lake is not pristine and already contains substantial quantities of sulfate. However, if nothing is done to contain the plumes, the plumes will inevitably reach the Jordan River and potentially affect all aquatic species living in the river and in the adjacent wetlands.

8. *Description of aquifer and ground water movement:*

Aquifers affected or threatened by site contamination, types of geologic materials, approximate depths, whether aquifer is confined or unconfined and direction of flow: There are three aquifers that are affected or potentially affected by the mining related contamination for the two zones. The following is a description of these aquifers starting with the bottom.

The bedrock aquifer underlies the entire valley at varying depths. The bedrock is close to the surface in the Oquirrh Mountains plunging to a depth of about 2000 feet below ground surface in the middle of the valley. The bedrock is composed of Paleozoic bedrock with a layer of Tertiary volcanic rock above it. Both provide recharge water to the Principal Aquifer. Hydraulic conductivity is low relative to the principal aquifer, but is highly variable depending on the presence or absence of fractures. The Eastside waste rock dumps are located on the Tertiary volcanic rock. When the water percolating through the dumps encounters the bedrock, it flows at the interface and emerges at the toe of the dumps. The degree to which the acid-laden waters enters the Bedrock Aquifer is unknown. The degree to which the waters are then discharged to the Principal Aquifer and where is also unknown. The USGS and Kennecott are beginning to develop a model which may provide insight on these issues. Hydraulic conductivities are 0.03 - 0.8 feet/day. The direction of flow is variable depending on the direction of the fractures.

About a mile east of the eastern front of the Oquirrh Mountains, the bedrock is overlain by the Jordan Valley Narrows Unit originating during the Oligocene-Miocene period. It is described as interbedded clays and tuff and is considered by most experts to be an aquitard. Its conductivity is estimated at 0.1 - 0.3 feet/day. This is the bottom of the Principal Aquifer. The Bedrock Aquifer discharges to the Principal Aquifer.

The Principal Aquifer overlies the bedrock layers near the mountains and the Jordan Valley Narrows Unit farther out in the valley. It consists primarily of Plio-Pleistocene alluvial fan deposits of quartzitic and volcanic gravel. In the central part of the basin, the aquifer is relatively thick (up to 1000 feet) and is composed of quartzitic gravels. The upper 200-300 feet of the aquifer is particularly productive with hydraulic conductivities of 3 - 83 feet/day at the western part and over 100 feet/day east of the Evaporation Pond site in Zone B. At the southern part of the site near the mountains, the Principal Aquifer is mostly volcanic gravel interbedded with clay and silt. The hydraulic conductivities in this area range 1 - 12 feet/day. The Bingham Reservoir and the Lark tunnel portals are both located in the recharge zone of the Principal Aquifer at the edge of the mountains in Zone A. The relatively high hydraulic conductivities allowed the contamination to spread quickly. The flow of the Principal Aquifer is generally eastward with minor directional changes in the presence of buried channels. The flow bends toward the northeast near the Jordan River boundary (toward the direction of the Great Salt Lake). The Principal Aquifer is considered to be unconfined in the area near the mountains (Zone A), but is thought to be confined between the Evaporation Ponds and the Jordan River (Zone B). The confining layer has not been thoroughly investigated and may not be continuous. The Principal Aquifer eventually discharges to the Jordan River and the Great Salt Lake.

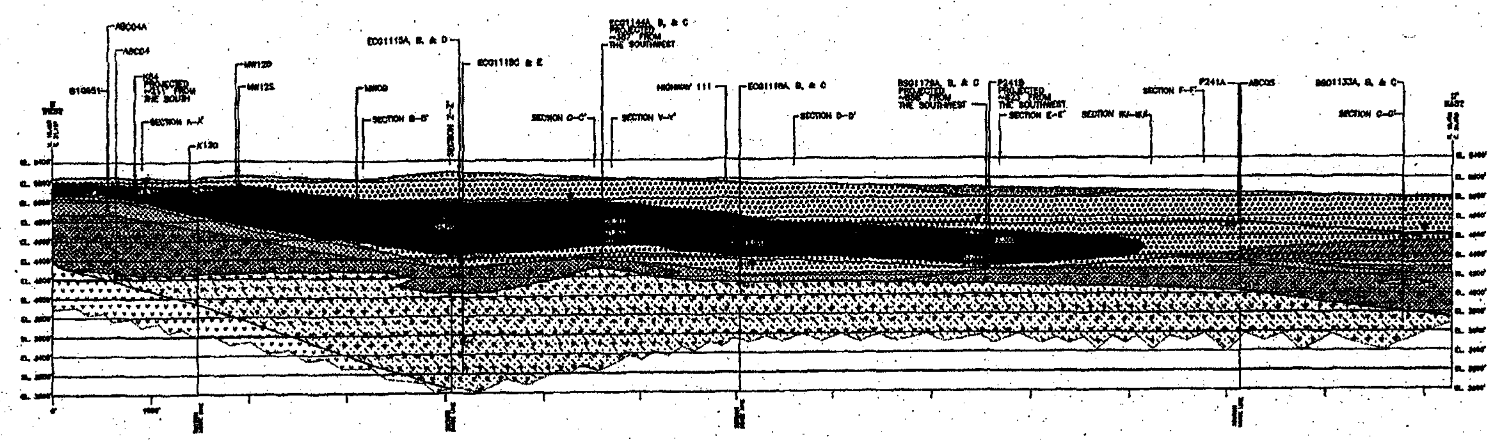
The Shallow Unconfined Aquifer is found east of the Evaporation Ponds (Zone B) and consists of quartzitic gravel intermixed with silt and clay. They are Bonneville and Provo lacustrine deposits (Late Pleistocene and Holocene). The conductivity is low at about 1 ft/day. The flow direction is toward the east. The South Jordan Evaporation Ponds contaminated both the Shallow Unconfined Aquifer and the Principal Aquifer in Zone B. The Shallow Unconfined Aquifer is also affected by several unlined irrigation canals which traverse the area. The shallow aquifer discharges to springs and seeps along the Jordan River.

Surface and subsurface features: Features at the site which affect the quality of the ground water include the mining-related sources and several non-mining related sources. Mining related sources include the former Small and Large Bingham Reservoirs (now reconstructed with triple linings and leak detection), the former Eastside Leachate Collection System (now reconstructed with cutoff walls keyed into bedrock and with above ground HDPE pipes), the Bingham Tunnel portal (the tunnel discharge now goes into the reconstructed Eastside Collection System), the Lark Tailings and Waste Rock (now remediated), all in Zone A, and the South Jordan Evaporation Ponds (retired from service, remediated, and partially redeveloped as residential property) in Zone B. The major non-mining related sources are a series of unlined irrigation canals which are in use during the growing season with waters mainly from Provo River and Utah Lake. Because others have wells in the area, agencies are aware that any increased pumping could draw the plume in that direction, reduce water levels, or both.

Stratigraphy: An example of the stratigraphy with location of the contaminated plume is shown in Figure 6 (Figure 4-8, from the Remedial Investigation Report). The monitoring well map is shown in Figure 7 (Figure 3-5a, also from the Remedial Investigation Report).

Ground water models: Hydrologic, geochemical and contaminant transport models were used to predict flow rates and contaminant movement. The flow model uses a three-dimensional, finite difference, numerical code called MODFLOW. This model code is accepted internationally and was also used by the U. S. Geological Survey in their development of the Salt Lake Valley Ground Water Model. The model was verified using historical ground water monitoring data. The geochemical modeling used PHREEQC, also widely used. The contaminant transport was modeled using MT3D. Assumptions are given in detail in the RI Report and Appendices.

The time required to remediate the aquifer using the various alternatives was estimated using the models described above. Although substantial ground water and aquifer data were used in the modeling effort, models, by their very nature, have uncertainties associated with them. For example, the ground water may encounter a heretofore unknown buried creek channel which may cause the plume to change direction and/or flow rate. Therefore, the time required for the plume to travel and the time for remediation are estimates only. Continued monitoring would be needed for all the alternatives to detect unexpected results in sufficient time to plan responses.



SECTION U – U'
LOOKING NORTH
NO VERTICAL EXAGGERATION

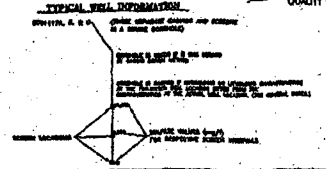
WATER QUALITY DATA FOR SECTION U – U'

WELL ID	DATE SAMPLED	SO4 mg/l	pH	SOURCE
B10951	7-29-96	29,400	3.3	KEL
ABC04A	5-1-96 *	75	7.2	KEL
AB004	3-29-96 *	30	7.3	KEL
K84	6-13-96 *	10,100	3.6	KEL
K120	6-13-96 *	26,300	3.2	KEL
MW12D	NO RECENT DATA			
MW12S	NO RECENT DATA			
MW09	NO RECENT DATA			
EC01115A	7-15-96	34,800	3.3	KEL
EC01115B	7-12-96	2,360	7.1	KEL
EC01115C	7-10-96	4,860	6.6	KEL
EC01115D	7-10-96	36	7.6	KEL
EC01115E	12-7-95 *	44	7.2	KEL
EC01144A	8-22-96	26,200	3.4	KEL
EC01144B	4-9-96 *	21,600	3.7	KEL
EC01144C	8-20-96	100	7.4	KEL
EC01118A	7-2-96	18,000	3.5	KEL
EC01118B	7-1-96	106	7.7	KEL
EC01118C	2-16-96 *	83	7.4	KEL
BS01179A	6-16-97	19,200	3.6	KEL
BS01179B	6-16-97	13,000	3.8	KEL
BS01179C	6-16-97 *	23,000	3.8	KEL
P241B	8-19-96	14,300	3.6	KEL
P241A	8-20-96	4,800	5.8	KEL
ABC05	8-20-96	34	7.7	KEL
BS01133A	7-5-96	3,770	6.5	KEL
BS01133B	7-5-96	376	7.2	KEL
BS01133C	6-25-96 *	31	7.6	KEL

EXPLANATION FOR SOURCE	
KEL	KENNECOTT ENVIRONMENTAL LAB.

* THIRD QUARTER 1996 (JULY–SEPTEMBER) WATER QUALITY DATA USED EXCEPT WHERE NOTED BY *.

TYPICAL WELL INFORMATION



LEGEND:

WATER QUALITY:

- pH < 4.5 AND SO4 > 2,000 mg/l
- SO4 > 2,000 mg/l
- SO4 250–2,000 mg/l
- SO4 < 250 mg/l
- WATER QUALITY CONTACT NEAR WELL CONTROL
- INFERRED WATER QUALITY CONTACT

LITHOLOGY:

- QUARTZITIC GRAVEL
- INTERBEDDED QUARTZITIC GRAVEL AND CLAY
- VOLCANIC GRAVEL
- INTERBEDDED VOLCANIC GRAVEL AND CLAY
- INTERBEDDED CLAY AND TUFF
- VOLCANIC BEDROCK

- POTENTIOMETRIC SURFACE
- GEOLOGIC CONTACT NEAR WELL CONTROL
- INFERRED GEOLOGIC CONTACT
- BOTTOM OF PRINCIPAL AQUIFER NEAR WELL CONTROL
- INFERRED BOTTOM OF PRINCIPAL AQUIFER
- LIMIT OF LITHOLOGIC INTERPRETATION

GENERAL NOTES:

- REFER TO FIGURE 1–2 FOR SECTION LOCATIONS.
- THIS SCHEMATIC SECTION REPRESENTS THE GEOLOGY, WATER TABLE, AND/OR WATER QUALITY INTERPRETED TO EXIST AT THE SECTION LOCATION. MANY WELLS HAVE BEEN PROJECTED ONTO THE SECTION, AND CONSEQUENTLY SOME (THOSE WITH DASHED BOREHOLES) MAY NOT HAVE THE CHARACTERISTICS DEPICTED AT THEIR PROJECTED LOCATIONS.

ENGINEERING SERVICES

KENNECOTT UTAH COPPER

SCALE: NONE

JF

CDC

JKL

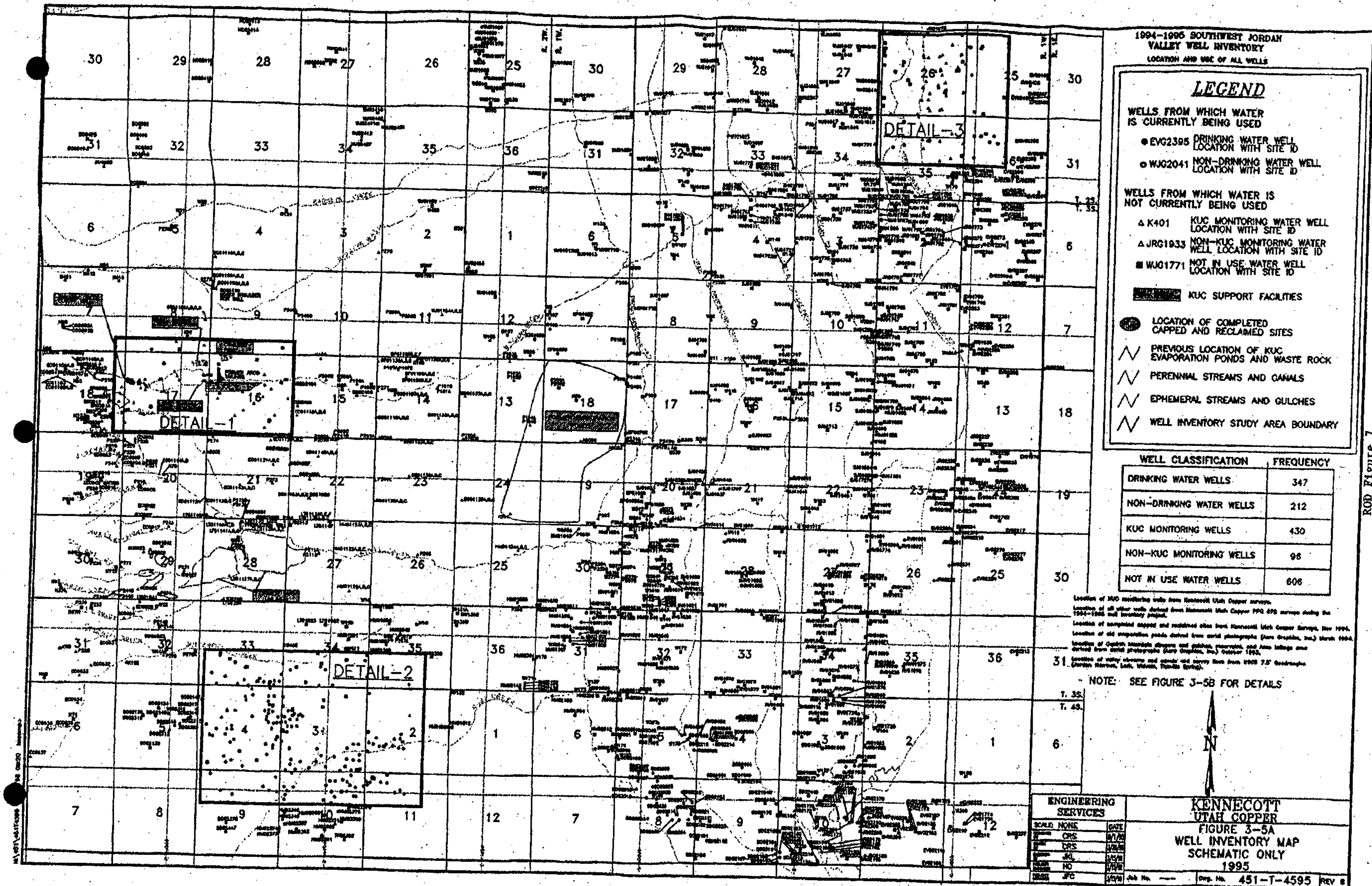
HO

JFC

FIGURE 4–8
GEOLOGIC CROSS-SECTION U–U'

Dwg. No. 451–T–4633

ROD Figure 6



WELL CLASSIFICATION	FREQUENCY
DRINKING WATER WELLS	347
NON-DRINKING WATER WELLS	212
KUC MONITORING WELLS	430
NON-KUC MONITORING WELLS	96
NOT IN USE WATER WELLS	606

ROD Figure 7

F. Current and Potential Future Site and Resource Uses:

1. *Land Use*:

The contaminated ground water plumes in both Zones A and B underlie a suburban area of Salt Lake Valley, particularly the eastern portion of the site in Zone B. The western portion in Zone A is still largely agricultural and mining, but suburban development pressure is marching westward into this zone too as more infrastructure such as highways and water service become available. Several of the cities in the nearby area have already annexed these western lands in anticipation of the development. A map of current land use is given in Figure 8 (Figure 3-6, from the Remedial Investigation Report). The Wasatch Front Regional Council estimates that the population density above the plumes was 1.06 persons/acre in 1998. They estimate that the density will increase three fold by 2020. Growth rate is estimated at 6% per year for the next 20 years.

2. *Ground/surface water uses on the site and in its vicinity*:

Current water use: There are three creeks which traverse the two zones from their headwaters in the Oquirrh Mountains and discharge into the Jordan River. The Jordan River, in turn, discharges to the Great Salt Lake. Kennecott has a cutoff wall and reservoir at the mouth of the Bingham Canyon which capture all the flow of Bingham Creek from the Oquirrhs, in addition to other waters from mining operations. The water is used in mineral processing at the Copperton Concentrator. The headwaters of Midas Creek/Copper Creek are now buried by waste rock from the Bingham Canyon Mine and waters which formally flowed in this former drainage have also been diverted by the mining company for use in mineral processing. The total flow in Butterfield Creek along the southern boundary of the site is diverted by the Herriman Irrigation Company and used for irrigation of agricultural lands and residential yards in and near Herriman. Most of the creeks are essentially dry by the time they leave the foothills of the Oquirrhs. The county flood control district has relocated some of them to provide better drainage following storm events. Flows from the Jordan River are diverted by canals to irrigation districts. The outfall of the local waste water treatment plant is located just downstream of the site on the Jordan River.

There are four cities which overlay the contaminated plumes. Two of the cities, West Jordan and Riverton, have their own municipal well fields but also augment their water supplies with water provided by the Jordan Valley Water Conservancy District (JVWCD). One of the cities, South Jordan, depends entirely on drinking water supplied by the JVWCD. The Town of Herriman currently depends on private wells and a private water supply company, the Herriman Pipeline Company. There are also some areas which are in unincorporated Salt Lake

County. These areas are serviced by private wells, the Copperton Improvement District, and the Jordan Valley Water Conservancy District.

The Jordan Valley Water Conservancy District obtains its water largely from surface sources outside the site including the Jordanelle, Deer Creek, and Echo Reservoirs, some high Uinta lakes, the Provo and Weber Rivers, five Wasatch Front mountain streams, and some Wasatch Front springs. The JVWCD does own water rights in the affected area. However, these rights have not been developed.

West Jordan's municipal well field is located just to the north of the acid plume in Zone A and there is concern that excess pumping by the city could draw the contamination into that direction. Also, there is concern that excess pumping as a part of any remedy could lower the water table in the area so low as to reduce the capacity of West Jordan's wells and other wells in the area.

Riverton's municipal well field is located just to the south of the sulfate plume in Zone B and one well has already been impacted.

South Jordan has no water rights and has not sought to procure any because of the poor quality water.

The Town of Herriman's main water source is the Herriman Pipeline Company which obtains its water from wells outside the acid plume in Zone A. Town officials are concerned that the town will outgrow this water source and new supplies may be needed. They are already in negotiations with JVWCD to provide this additional water. Herriman is largely rural and several properties are served by private wells owned by individuals and small water companies. Several of these wells have declining water quality.

The Copperton Improvement District well is located outside and upgradient of the acid plume in Zone A and is not threatened by the contamination.

A summary of the municipal water use provided by the various suppliers is given in the following table:

WATER SUPPLIERS AND SOURCES OF WATER

Supplier	Surface water (acre-feet/year)	Groundwater (acre-feet/year)
Copperton	0	337.2
Dansie Water Co (Herriman)	0	75.0
Herriman Pipeline Co.	166	156.3

Supplier	Surface water (acre-feet/year)	Groundwater (acre-feet/year)
Hi-Country Estates I	0	35.6
Hi-Country Estates II	0	53.2
Riverton	493.1 (from JVWCD)	3,366.3
South Jordan	5,153.3 (from JVWCD)	0
West Jordan	5,217.8 (from JVWCD)	6,601.2

The annual water use is 21,631 Acre-ft/yr (1995 data).

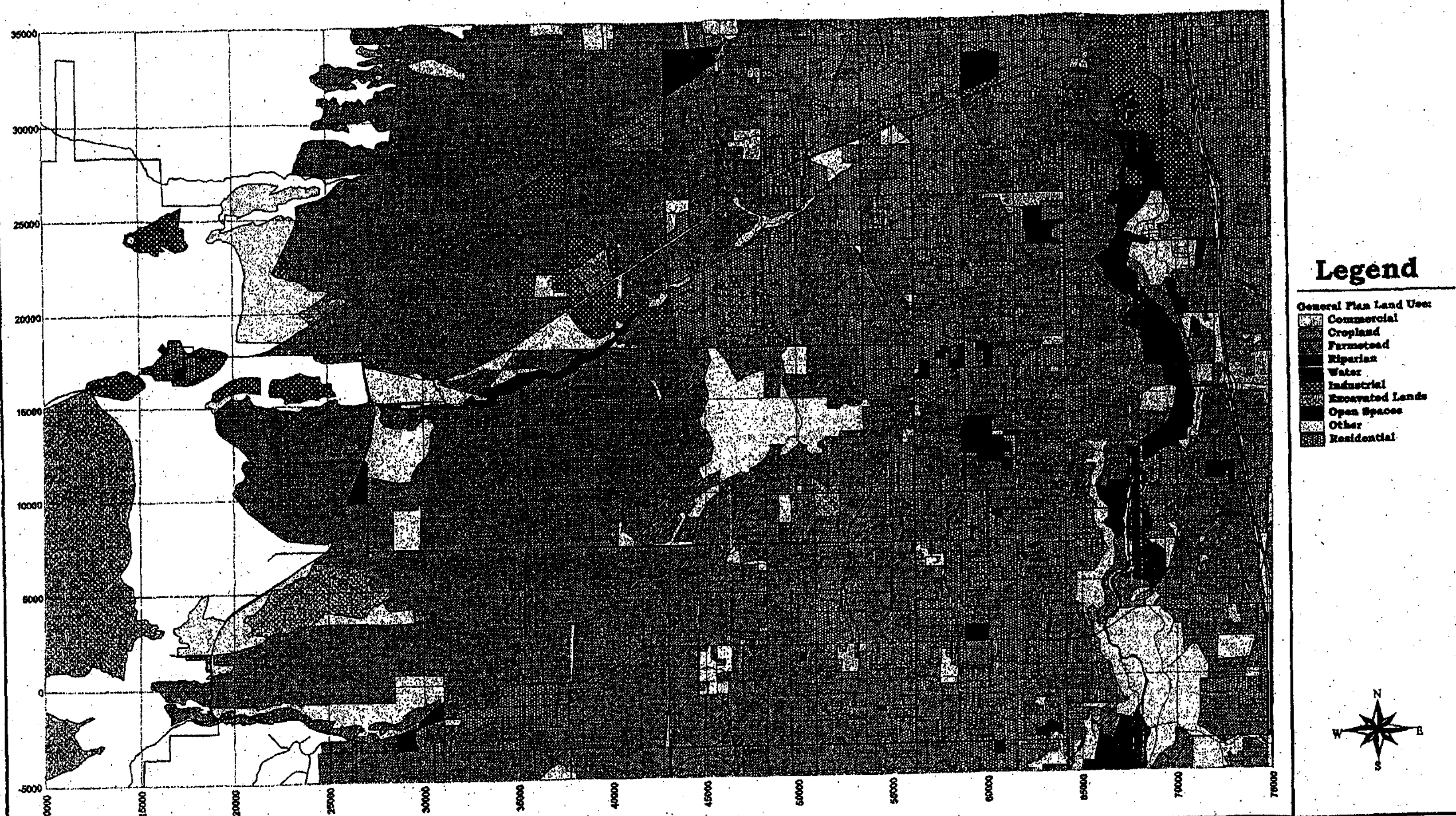
The water in the study area is used for a variety of purposes as approximated in the following table, from the RI/FS (Water use in units of acre-feet/year):

TYPES OF WATER USES

Supplier	Domestic	Commercial	Industrial	Irrigation	Other
Copperton	178.0	159.2			
Dansie	36.8			3.1	33.8
Herriman	217.9			104.4	
Hi-Country I	35.3				0.3
Hi-Country 2	53.2				
Riverton	3,471.9	383.6			
S. Jordan	3,973.0	477.5			
W. Jordan	9,972.3	153.4	1,534.2	184.1	

Kennecott conducted a Well Inventory as a part of the Remedial Investigation/Feasibility Study. Of the 1,688 wells inventoried at the site, 523 were monitoring wells (31%), 559 were in use (33%), and 606 were not in use, damaged, or missing. Of the 559 wells in current use, 347 were for culinary use and 212 for other uses. Other uses include irrigation, stock watering, commercial and industrial uses. When wells of declining water quality were found, Kennecott worked with the owners to provide alternative water supplies.

Anticipated Use: It is quite clear that the water needs of the area will increase. Based on the population growth in the area as estimated by the Wasatch Front Regional Council, the Jordan Valley Water Conservancy District estimates that the water demand of their service area will double in the next 20 to 25 years. Their current water supply for their entire service district is about 70,000 acre-ft/yr. By 2020, the district projects it will need about 160,000 acre-ft/yr. If the same growth rate is used for the impacted area, the water needs for population growth above the contaminated aquifer could increase from 22,000 acre-ft/yr to 50,000 acre-ft/year. Although the contaminated groundwater is currently not being utilized except by Kennecott as industrial waters and a few private well owners for irrigation, full utilization of the impacted groundwater is desired by the cities and the water purveyors because the water is near the population. Since the safe annual yield of the aquifer is estimated at 7,000 acre-ft/year, alternative sources of water from outside the area will be needed as well.



ROD Figure 8

1 0 1 2 Miles

Derived from Utah Division of Natural Resources Division of Water Resources Land Use/Land Cover Classification(1985-1992)

Coordinate System: KUC TN Mine Grid

Note: Diagram has been modified to reflect KUC current(1997) land use. Land use elements from UDNR map have been combined for simplicity.

ENVIRONMENTAL ENGINEERING PROJECTS GROUP GIS SERVICES

		DATE
	MWH	10/13/97
	RE	3/6/98
	HO	3/9/98

Kennecott Utah Copper

Figure 3-6
1997 Land Use in Study Area

Project File: r:/projects/craig/lfa.apr

G. Summary of Site Risks:

1. *Summary of Human Health Risk Assessment:*

The baseline risk assessment estimates what risks the site poses if no action were taken. It provides the basis for taking action and identifies the contaminants and exposure pathways that need to be addressed by the remedial action. This section of the Record of Decision summarizes the results of the baseline risk assessment for this site.

For the purposes of this project, a full traditional risk assessment was not performed. Instead because EPA and UDEQ have adopted drinking water standards and the ground waters in the valley are a potential and actual drinking water source, for most cases the concentrations of the chemicals of concern in the ground water were simply compared to the drinking water standards. With the exception of sulfate, which has no primary standard adopted by EPA, any exceedance of primary drinking standards presents an unacceptable risk to anyone drinking this water. Because sulfate concentrations are the most pervasive chemical of concern at the site, the risk assessment focused largely on estimating the concentration of sulfate that produces unacceptable health impacts to sensitive populations. A Risk Assessment Task Force, composed of toxicologists and epidemiologists from EPA, Utah Department of Environmental Quality, Utah Department of Health, Salt Lake City/County Department of Health, City of West Jordan, and Kennecott, aided EPA and its contractor in collecting research papers, evaluating the quality of the research, and recommending the level of concern.

a. *Identification of Chemicals of Concern*: The following table describes the various concentrations found in the acid plume downgradient of the Large Bingham Reservoir:

CONCENTRATIONS OF CHEMICALS OF CONCERN
(From Remedial Investigation Report, Table 4-8; All concentrations are in mg/L unless noted)

Chemical	No. of samples	Minimum value	Maximum value	Mean	Std. Dev.	% not detected
pH*	336	**2.6**	6.87	**4.33**	1.22	0
TDS	336	**1236**	**77574**	**28000**	22000	0
bicarbonate	58	<1.0	780	130	150	17
chloride	308	41	**539**	190	75	0
fluoride	58	<0.1	**16.2**	**2.4**	3.8	19

Chemical	No. of samples	Minimum value	Maximum value	Mean	Std. Dev.	% not detected
sulfate	337	**426**	**59,000**	**20,000**	16,000	0
calcium	280	8	1040	420	160	0
magnesium	290	127	8640	2600	2200	0
potassium	279	<0.01	70	7.2	5.9	4
sodium	290	24	910	100	92	0
nitrate	79	<0.01	4.5	0.67	0.95	41
aluminum	124	<0.005	**4690**	**910**	1200	16
arsenic	276	<0.001	**4.1**	0.040	0.27	38
barium	234	<0.005	0.9	0.024	0.065	51
cadmium	277	<0.001	**9.34**	**0.42**	1.1	16
chromium	234	<0.002	0.99	0.078	0.13	39
copper	277	<0.001	**192**	**47**	49	15
iron	148	<0.01	**1222**	**250**	320	5
lead	277	<0.001	**0.85**	**0.034**	0.13	55
manganese	146	0.01	**1100**	**180**	180	0
nickel	129	<0.01	**850**	**18**	75	3
selenium	277	<0.002	**0.9**	0.022	0.081	55
silver	234	<0.001	**0.24**	0.014	0.030	64
zinc	239	<0.01	**544**	**69**	68	2

* negative log of H concentration
bold values exceed either a primary or secondary drinking water standard

As demonstrated in this table, the components with maximum concentrations in the ground water exceeding either a primary or secondary drinking water standard include pH (acidity), total dissolved solids, chloride, fluoride, sulfate, aluminum, arsenic, cadmium, copper, iron, lead, manganese, nickel, selenium, silver and zinc. Even the mean concentrations of several components exceed primary or secondary standards, including pH (acidity), total dissolved solids (TDS), fluoride, sulfate, aluminum, cadmium, copper, lead, manganese, nickel, and zinc. Because the concentration values are widely variable and can migrate, the maximum concentration was used for the exposure point assessment. These concentrations are located in the core of the acid plume.

b. *Exposure Assessment*

Potentially exposed populations in current and future scenarios: Currently, the public is not being exposed to the ground waters of the acid plume. This is because the acid plume is still underneath Kennecott property currently and Kennecott holds the water rights to this water. However, if nothing is done to contain the plume in perpetuity or treat it, the contaminated ground water will continue to move down gradient in the aquifer eventually leaving Kennecott property. Theoretically, at that time, any citizen, municipality, or business that has a water right in the impacted ground water area could access the contaminated water causing their household, customers, and workers to be exposed to unacceptable concentrations of acids, metals, and sulfate in their drinking water. If nothing is done to prevent the continued movement of the plume, more and more wells in the path downgradient of the plumes would degrade in their quality. At least one municipal well field, perhaps two, are also threatened. The situation would only get worse with the passage of time.

The worst case scenario is theoretically possible. There are currently about 800 water rights holders in this area including two municipalities. Absent any institutional controls approved by the Utah State Engineer, additional water rights could be granted and well permits issued to anyone. In addition, several wells were found where the property owner did not possess a water right or a well permit at all. The worst case scenario is unlikely because the State Engineer will probably approve institutional controls to prevent exposure and few citizens would invest the money to drill a well in a known area of contamination.

Any sensitive populations: There are two populations sensitive to excessive levels of sulfate, the most pervasive chemical of concern. Excessive levels of sulfate in drinking water produces diarrhea, a problem which is annoying, but not particularly life threatening, except in infants. Infants with diarrhea can quickly become dehydrated. For this reason, pediatricians warn against making infant formula with waters high in sulfate. Medical evidence shows that adults and older children can build up a tolerance to high sulfate with repeated exposures. Visitors to any area with elevated sulfates in the drinking water would feel the effects to a greater degree than the resident population. Visitors would include household guests, and tourists patronizing local hotels, restaurants, tourist attractions, and commercial establishments.

Route of exposure: The route of exposure is ingestion of contaminated ground water for adults, children, infants, and visitors. Other routes of exposure such as uptake of metals and sulfate from irrigation waters into garden vegetables, dermal exposure, and inhalation were not quantified.

Assumptions: A traditional risk assessment was not conducted for this operable unit because drinking water standards have already been developed by EPA and adopted in regulations by the State of Utah. Therefore, the assumptions used at the site are the assumptions used to derive the national and state drinking water standards. It should be pointed out that some of the drinking water standards are based on more than health concerns; some include recognition of the treatment technologies available at the time of promulgation. As a result, some of the drinking water standards are under review, e.g., for lead and arsenic.

c. *Toxicity assessment*

According to the EPA Office of Ground Water and Drinking Water, the effects of drinking water exceeding the primary standards are given in the following table:

HEALTH EFFECTS OF ELEVATED INORGANIC COMPONENTS IN DRINKING WATER

Drinking water component	Potential Health Effects from ingestion of water exceeding the primary drinking water standard
Arsenic	Skin damage, circulatory system problems, increased risk of cancer
Barium	Increase in blood pressure
Cadmium	Kidney damage
Chromium	Allergic dermatitis
Copper	Gastrointestinal distress, liver or kidney damage
Fluoride	Bone disease, mottled teeth
Lead	Delays in mental development, kidney problems, high blood pressure
Nitrate	blue baby syndrome
Selenium	hair or fingernail loss, numbness, circulatory problems

EPA has not yet adopted a federal primary drinking water standard for sulfate. This is mainly because there is little medical evidence and in some cases the information is contradictory. The State of Utah adopted a primary sulfate drinking water standard of 500 ppm to 1000 ppm, depending on whether the use was principally residential. The risk assessment evaluated the available toxicological information and medical research on sulfate to establish a health based goal for this project. This re-evaluation was conducted because sulfate is the most pervasive chemical of concern in the acid plume.

The risk assessment determined that the main effect of elevated concentrations of sulfate was diarrhea. The effect was short-lived because people appear to develop a tolerance after about a week of exposure. Therefore, residents of an area may not show any symptoms of high sulfate exposure; whereas, visitors to the area could be affected. Although diarrhea is an annoying condition to adults, it can be potentially dangerous to infants. Because of their low body weight, diarrhea can cause dehydration quickly in infants. An examination of the literature determined that few if any effects would occur even to visitors and infants if concentrations of sulfates are kept below 1500 ppm.

d. *Risk Characterization*:

The concentrations of contaminants in the ground water were compared to primary drinking water standards and the health based sulfate level which were used as benchmarks in the following table. In this comparison, the ratio of the acid plume concentrations to the drinking water standard or safe level is analogous to a Hazard Quotient.

RISK OF CHEMICALS OF CONCERN IN ACID PLUME

Chemical of Concern	Primary Drinking Water standard or health based level (mg/l)	Maximum concentration in acid plume (mg/l)	Ratio acid plume/safe level (analogous to a Hazard Quotient)
Arsenic	0.05	4.1	82
Barium	2	0.9	0.45
Cadmium	0.005	9.34	1868
Copper	1.3 (action level)	192	147

Chemical of Concern	Primary Drinking Water standard or health based level (mg/l)	Maximum concentration in acid plume (mg/l)	Ratio acid plume/safe level (analogous to a Hazard Quotient)
Fluoride	4	16.2	4.05
Lead	0.015 (action level)	0.85	56.6
Nitrate	10	4.5	0.45
Selenium	0.05	0.9	18
Nickel	0.1 (Utah standard)	850	8500
Sulfate	1500 ppm health-based level; 500 ppm Utah primary standard	59,000	39.3, based on health based standard; 117.9, based on state primary standard

In this case, the ratios (hazard quotients) are not additive since the contaminants affect different organs and tissues. Most of the metals in the ground waters within the acid plume are in excess of drinking water standards, sometimes by a factor of thousands. The predominant exposure pathway is ingestion of the contaminated ground water.

There are several uncertainties associated with estimation of risk from exposure to the contaminated ground water of the acid plume. (1) There are no current exposures to the ground water. Several private well owners have already been hooked up to municipal systems. Kennecott has purchased additional lands to limit access. Therefore, the risk associated with the plume is a future risk assuming that nothing further will be done. Because of the complex chemistry which occurs as the acid plume moves (neutralization, precipitation, redissolution, etc.), the calculations were based on the current concentrations in the plume, not what the plume might contain in the future. This assumption would likely overestimate future risk. (2) Drinking water standards are largely health based, but do contain some consideration for the drinking water treatment technologies routinely available at the time of promulgation. This could mean that the risk could be underestimated. (3) The scientific literature on the health impacts of sulfate is sparse and sometimes contradictory. Because of this uncertainty, EPA has chosen to use a fairly conservative health-based level.

2. *Summary of Ecological Risk Assessment*

The ecological risk assessment estimates what risks the site poses if no action were taken. It provides the basis for taking action and identifies the contaminants and exposure pathways that need to be addressed by the remedial action. This section of the Record of Decision summarizes the results of the Ecological Risk Assessment for this site.

In a strategy analogous to the human health risk assessment, the ecological risk assessment was streamlined and focused on the impacts of ground water recharge to the Jordan River and additional loads of contaminants that might be expected in the near and distant future. The concentrations of contaminants in the river with the projected additional loads were then compared to Utah Water Quality Standards for the river. The exposure point was assumed to be that stretch of river that intersects the path of the groundwater flow.

a. *Current and near future water quality impacts from ground water:*

The ecological risk assessment studies compared the concentrations of contaminants in the river with contaminants in nearby monitoring wells to estimate if any ecological impacts might be present or anticipated in the near future. The following table gives the results of this investigation updated with the most recent water quality standards.

COMPARISON OF WATER QUALITY IN WELLS WITH JORDAN RIVER WATER QUALITY STANDARDS (Updated from RI/FS)
Jordan River Narrows to Little Cottonwood Creek segment

Contaminant	Jordan River concentrations	Concentrations in nearby ground water wells	Utah Water Quality Standards for Jordan River segment (4-day, aquatic life 3a class)
TDS	973 mg/l (upstream) 1135 mg/l (downstream)	not given	1200 ppm (agricultural use standard, none for aquatic life)
Cadmium	2.0 ppb or less	<2.0 ppb	1.1 ppb
Copper	20 ppb or less	19 ppb	12 ppb
Selenium	<3 ppb	9 ppb	5 ppb

Contaminant	Jordan River concentrations	Concentrations in nearby ground water wells	Utah Water Quality Standards for Jordan River segment (4-day, aquatic life 3a class)
Zinc	11 ppb	252 ppb	110 ppb
Sulfate	248 mg/l (upstream) 309 mg/l (downstream)	432 mg/l	no standard - calculated from literature 505 mg/l

The concentrations in the ground water of wells near the Jordan River exceed the Utah Water Quality Standards for the Jordan River for copper, selenium, zinc, and perhaps others. After mixing with other waters in the river, the concentrations in the river may eventually exceed the standard in the near term but not excessively so. Kennecott asserts that the contaminants do not come from mining activity but from irrigation and other sources.

b. *Sources of water to the Jordan River segment of interest*:

Although the average flow of the Jordan River during the irrigation season has been estimated near Utah Lake at 204,000 gpm, nearly 100% of the river is diverted by irrigation canals during the irrigation season. The average flow of the river near the site (9000 South) is 40,000 gpm during irrigation season. The ground water model results suggests that 21,400 gpm (53%) of this flow originates from ground water discharge from the western part of the valley (the location of this site), 7,200 gpm (18%) from the eastern side of the valley, and 11,800 gpm (29%) from return flow from the irrigation canals.

c. *Future ecological risk*:

Although the current or near term risk appears to be low for the contaminants associated with the ground water, a different picture altogether emerges if the acid plume is allowed to reach the Jordan River. Ground water modeling suggests that this could occur in 150 years if nothing is done to contain the plume. The following table illustrates what could happen in this circumstance.

POTENTIAL CONCENTRATIONS OF CONTAMINANTS IN JORDAN RIVER IF ACID PLUME IS NOT CONTAINED (updated from the RI Report)

Contaminant	Average Jordan River concentration (average of upsteam and downstream)	Average concentration in acid plume (1997)	Jordan River after mixing with acid plume (assuming a 1:20 mixing ratio, year round)	Water Quality Standard (4-day, aquatic class 3a, Jordan River)	Ratio of future Jordan River to standards
Sulfate	278 mg/l	18,000 mg/l	1039 mg/l	no standard, 505 mg/l calculated from literature	2.06
TDS	1054 mg/l	25,000 mg/l	2195 mg/l	1200 mg/l, agricultural use standard	1.83
Cadmium	< 2 ppb	620 ppb	29.1 ppb	1.1 ppb	26.4
Copper	<20 ppb	41,000 ppb	1818 ppb	12 ppb	151.5
Selenium	<3 ppb	14 ppb	4.3 ppb	5.0 ppb	0.86
Zinc	11 ppb	67,000 ppb	2933 ppb	110 ppb	26.7

This calculation demonstrates that the water quality of the Jordan River would decline seriously should the acid plume be allowed to reach the river. The situation is actually worse during irrigation season when there is essentially no dilution factor available because the flows in the river are less.

d. *Uncertainties*:

The uncertainties inherent in these calculations are numerous. The assumptions are particularly uncertain. (1) This calculation assumes that the acid plume will eventually reach the Jordan River. However, the acid plume is in the principal aquifer rather than the shallow aquifer. It is known that the shallow aquifer discharges to the river. The principal aquifer may go underneath it or discharge to it at a much slower rate. The calculations, therefore, represent a worst case scenario. (2) This calculation assumes that the average concentrations in the acid plume currently would reach the river with its concentrations unmodified by dispersion or reactions with the aquifer solids. This is very unlikely. By the time the acid plume reaches the river, concentrations of contaminants are likely to be much less. Again, the calculations represent a worst case scenario. (3) These calculations assume that the water quality in the river will remain the same in the future as they are today. Although improving water quality in the river will not help much if the acid plume does reach the river, declining water quality in the river could make the situation worse. (4) The mixing ratio varies seasonally. The calculations represent the annual average. During irrigation season the influence of ground water on the Jordan River is much more important than during the rest of the year. (5) The ground water flow rates to the river are based on the ground water model for the site and, therefore, are affected by the uncertainties associated with the use of the model. These uncertainties are just a few examples of the difficulties in estimating risk far into the future.

3. *Basis for action*

Absent limitations on access to the ground water, human health could be at risk to anyone seeking to use the water for culinary purposes. The water quality fails to meet primary standards and health based levels. It is also not suitable for municipal supplies without treatment because it violates a host of secondary standards. In some cases the water is unuseable even for secondary uses such as irrigation due to its acidity.

If nothing is done, the acid plume will continue to move toward the Jordan River where it could impact the Jordan River's aquatic life, perhaps severely.

H. Remedial Action Objectives:

1. Minimize or remove the potential for human risk (by means of ingestion) by limiting exposure to ground water containing chemicals of concern exceeding risk-based concentrations or drinking water Maximum Contaminant Levels.

    a. Human health risk is minimized by either reducing the contaminant levels or cutting off the exposure pathway.

    b. Contaminants, which could be ingested, can be decreased by reducing the concentrations in the aquifer itself to drinking water standards or treating the ground waters to drinking water standards before it is used.

    c. The exposure pathway can be cut by limiting access to the ground water and obtaining water from another source.

2. Minimize or remove the potential for environmental risk (by means of flow of ground water to the Jordan River) to receptors of concern.

    a. Ecological risk is minimized only by reducing the contaminant levels.

    b. Contaminant levels could be decreased only by reducing the concentrations in the aquifer itself.

3. Contain the acid plume and keep it from expanding.

    a. Containment of ground water plumes is the expected minimum for ground water actions in the National Contingency Plan.

    b. Allowing the plume to move farther will contaminate additional ground water, including at least one municipal well field, and damage additional aquifer materials.

    c. Maintain sulfate-laden ground water in excess of 1500 mg/l west of the Kennecott property line in Zone A.

4. Remediate the aquifer over the long term

    a. Ground water in this aquifer is a resource that is needed by the public both now and in the future as communities grow westward toward the Oquirrh Mountains.

b. Remediation is the only long term option which is totally effective in preventing the public from exposure to dangerous levels of contaminants in this ground water.

5. Return ground water to beneficial use.

   a. Return of ground water to beneficial use is an expectation of the National Contingency Plan.

   b. The site is located in a semi-arid climate. Ground water resources are needed to support additional population and development growth projections for the site.

I. Description of Alternatives

The Remedial Investigation/Feasibility Study evaluated six (6) alternatives. A number of others were rejected in the screening process. A summary of each of the six retained alternatives is given below:

1. *Alternative 1 - No Further Action.*

This alternative relies solely on natural attenuation to achieve long term remediation goals. This could take 800 years or longer. Citizens and municipalities would be responsible for limiting their own exposures.

a. *Major elements of Alternative 1:*

- Maintenance of source controls already implemented by Kennecott: (Kennecott has constructed a system to collect acid rock drainage which continues to emanate from their waste rock dumps. This must be maintained in order to prevent additional contaminants from entering the ground water.)
- Monitoring effectiveness of source controls as required in a State Groundwater Permit: (The state has issued a Ground Water Permit to Kennecott which requires Kennecott to monitor wells downgradient of their source controls to demonstrate that the controls continue to prevent further contamination.)
- Monitoring migration of the plume: (A monitoring network has been installed. In this alternative, movements of the plume could be determined and water users warned of the arrival of the acid plume.)

b. *Key ARARs:*

Continued participation in the State Ground Water Protection Program which requires the operations and maintenance of the source control measures is required. After mine closure the operations and maintenance of the source control measures must be maintained, perhaps as an element of the Mine Closure Plan administered by the Utah Division of Oil, Gas and Mining. In addition, chemical specific standards would be ARARs, but they would not be met.

c. *Long term reliability*:

The source control measures are well constructed and are likely to be reliable in the long term.

d. *Quantity of untreated waste and treatment residuals*:

Because there is no treatment, the quantity of untreated water actually grows as the plume gets further dispersed over time. There would be no treatment residuals as a result of this option other than those associated with source control.

e. *Estimated time for design and construction*:

The source control measures are already designed and constructed.

f. *Estimated time to reach remediation goals:*

None of the goals would be achieved for at least 800 years, perhaps longer.

g. *Estimated costs*: (Appendix M, RI/FS)

ESTIMATED COSTS FOR ALTERNATIVE 1

Activity	Capital costs	O+M costs for 30 years	net present value
Source controls (already implemented by Kennecott)	$127M already expended, not included in cost	$19.2M	$19.2M
Monitoring		$7.1M	$7.1M
TOTAL (discount rate = 7%)		$26.3M	$26.3M

h. *Use of presumptive remedies or innovative treatment*:

No presumptive remedies or innovative treatment technologies are used in this alternative.

i. *Expected outcome*:

This alternative relies entirely on natural attenuation leaving the public and municipalities to their own devices to prevent exposure. Eventually when the plume reaches the Jordan River, the aquatic ecosystem might be severely impacted.

2 *Alternative 2 - Institutional Controls*:

This would seek to prevent exposure to the public, but does nothing to contain or treat the plume itself.

a. *Major elements of Alternative 2*

- Restrictions on use of existing wells, as approved by the Utah State Engineer: (Measures include purchase of land and water rights; restrictions on land use to prevent use of wells through codes, covenants; and restrictions by either municipal, county or state government)

- Restrictions on drilling of new wells, as approved by the Utah State Engineer: (Purchases of water rights and land; restrictions on land use to prevent drilling of wells using codes, covenants, and restrictions by either municipal, county or the State Engineer.)

- Modifications of above restrictions as the plume migrates in the future

- Includes the measures in Alternative 1.

b. *Key ARARs*:

In addition to ARARs from Alternative 1, the key ARARs in this case would be the various Utah Water Rights Laws, Utah Well Drilling Regulations, and local building codes.

c. *Long term reliability*:

This relies on the citizens to conform to the letter and spirit of all restrictions that might be placed on them by their local governments and by the State Engineer. This is very unlikely. Circumvention of the water rights regulations and local ordinances is rather common because citizens view these as an infringement on their property rights. Enforcement would be very difficult. Although this might work temporarily, it would not be very reliable in the long term.

d. *Quantity of untreated waste and treatment residuals*:

Since there is no treatment the quantity of untreated water actually grows as the plume gets further dispersed over time. There would be no treatment residuals other than associated with source controls.

e. *Estimated time for design and construction*:

It is estimated that two years would be required to get all of the institutional controls in place.

f. *Estimated time to reach remediation goals*:

Although people might not be exposed to contaminated water, the plume continues to move eventually reaching the Jordan River. It could take 800 years for the contaminated plume to be flushed through the aquifer.

g. *Estimated costs:* (Appendix M, RI/FS)

ESTIMATED COSTS FOR ALTERNATIVE 2

Activity	Capital costs	O+M costs for 30 years	net present value
Activities in Alternative 1		$26.3M	$26.3M
Water rights and land purchase	$16M (2 years)		$16.5M
TOTAL	$16M	$26.3M	$42.3M

h. *Use of presumptive remedies or innovative treatment*:

No presumptive remedies or innovative treatment technologies are used in this alternative.

i. *Expected outcome*:

This alternative relies on natural attenuation but does prevent exposures to the public by limiting access to the water. When the plume reaches the Jordan River the aquatic life could be impacted, perhaps severely. The success depends on the cooperation of municipal, local and state government and all the citizens to cooperate with the regulations. This cannot be guaranteed in perpetuity.

3. *Alternative 3 - Point of Use Management:*

This alternative seeks to prevent exposure to the public but does nothing to contain or treat the plume itself.

a. *Major elements of Alternative 3:*

- Replace impacted private well water by connecting residences to existing municipal water supply systems. (Instead of simply banning further use of wells, private well owners are given replacement water from municipal systems with waters unaffected by the plume. Wells can still be used to provide irrigation water if the values are less than 1500 ppm sulfate.)

- Install household water treatment units (such as reverse osmosis) to treat water supplied to residences by private wells: (When municipal systems are not available, treatment of the private well water can be provide with in-home treatment units. Wells can still be used without treatment to provide irrigation water, if the values are less than 1500 ppm sulfate.)

- If municipal systems are impacted in the future, alternative water supplies would be required or a treatment plant installed: (Modeling suggests that the plume might impact at least one municipal well field. If this occurs, it will be necessary to build a treatment plant for these wells.)

- Includes all the measures in Alternatives 1 and 2.

b. *Key ARARs:*

In addition to the ARARS in Alternative 2, the key ARAR in this alternative would be the Utah Drinking Water regulations which apply to municipal services and drinking water quality at the tap.

c. *Long term reliability:*

Hooking people up to municipal supplies has long term reliability although there could still be exposure to residents with wells since the wells would not be shut off. Limitations on the kinds of uses would work for the current well owner, but may not be passed on to new owners. Because this would be necessary for a long period of time, there could still be occasional exposure. In-home treatment units require some effort on the part of the resident to maintain the units and replace them when necessary. Information about the need for this treatment might not be passed on to any new owners. In-home treatment systems would not work should the acid plume core reach a private well. This alternative does nothing to clean up the aquifer itself.

d. *Quantity of untreated waste and treatment residuals:*

Although there would be some treatment residuals produced within the in-home treatment units, the amount would be minimal and would end up with the trash at a municipal landfill. The quantity of untreated waste actually increases as the plume continues to spread out contaminating more and more water as it moves downgradient.

e. *Estimated time for design and construction*:

It might take two years to locate all the affected parties, design extensions to public water systems, and install in-home systems. Evaluation of the plume movement patterns would continue indefinitely to observe and mitigate future impacts as the plume moves.

f. *Estimated time to reach remediation goals:*

Although exposure to the public would be minimized in the short term, this alternative does nothing to remediate the aquifer. The plume would continue to move unimpeded toward the Jordan River where impacts might occur, perhaps severe impacts. The aquifer would take 800 years or longer to flush through the environment.

g. *Estimated costs*: (Appendix M, RI/FS)

ESTIMATED COSTS FOR ALTERNATIVE 3

Activity	Capital costs	O+M costs for 30 years	net present value
Activities in Alternatives 1 and 2	$16M	$26.3M	$42.3M
Municipal connections	$0.901M	not estimated	$0.901M
Household treatment units (400)	$0.618M	$0.64M	$1.3M
TOTAL (7% discount)	$17.6M	$27.2M	$44.8M

h. *Use of Presumptive remedies or innovative treatment*:

There are no presumptive remedies or innovative treatment technologies used in this alternative.

i. *Expected outcome* :

Private well owners would be protected from exposure to unacceptably high concentrations of contaminants in their well water because an alternative source of culinary water would be provided. The well owners could continue to use their wells for irrigation purposes, but could be exposed if they used the water inappropriately. Institutional controls would have to be in place, essentially in perpetuity to verify that well water is used properly. New owners may not be made aware of the problems. This alternative would do nothing to prevent the plume from eventually reaching the Jordan River perhaps causing severe impacts. Alternative 3 would do nothing to remediate the aquifer. Fresh water recharges would also become contaminated as they encounter the plume and the contaminated alluvium. The plume could take 800 years or longer to course through the system.

4. *Alternative 4 - Hydraulic Containment, Reverse Osmosis (RO) Treatment, Delayed Acid Plume Extraction, Nanofiltration (NF) Treatment and Delivery of treated water*:

Alternative 4 seeks to prevent exposure to the public, contain the contaminated water and eventually treat the contaminated plume.

a. *Major elements of the alternative*:

- Installation of a barrier well containment system at the leading edge of the acid plume: (The barrier well system seeks to prevent further downgradient migration of the plume.)

- Treatment of the water using reverse osmosis (RO) for the first 10 years: (The waters would initially be high in sulfate which could be treated successfully with RO. In 10 years, the core of the acid plume would migrate to the wells and RO would not be able to work, due to high concentrations of sulfate, heavy metals and acid..)

- After the first 10 years, pretreatment of the water will be necessary as the core of the acid plume migrates to the barrier well system: (Membrane technology, such as Nanofiltration (NF) is proposed for pretreatment. As the highly acidic waters encounter the barrier wells, pretreatment of the water to reduce contaminant concentrations will be necessary before it is sent for polishing at the RO plant.)

- Treated water would be delivered to a municipal water purveyor.

- Concentrates would be discharged into Kennecott's tailings line or into Kennecott's mineral processing water circuit.

- Includes all the measures in Alternatives 1, 2, and 3.

b. *Key ARARs*:

In addition to ARARs in Alternative 3, key ARARs include the Utah Drinking Water Regulations, Utah Public Water Supply requirements, the Utah Ground Water Protection Corrective Action program, RCRA, the Utah Pollutant Discharge Elimination Program permit regulations, and Utah Water Rights Laws.

c. *Long term reliability*:

While preventing exposures to water users downgradient, this alternative incorporates a barrier well system which would seek to prevent further downgradient migration of the plume. The long term reliability of the barrier system is questionable because the highly acidic waters eventually encounter the barrier wells and any leakage past these wells would cause significant amounts of contaminants to escape downgradient. However, the technology, reverse osmosis with nanofiltration pretreatment, has been shown in pilot tests to work on the plume and could be reliable with proper maintenance.

d. *Quantity of untreated waste and treatment residuals*:

At the end of the remedial action, there should be no untreated wastes. If a pumping rate of 3500 gpm is assumed, treatment residuals could be as high as 2100 gpm over the life of the project. Existing infrastructure for management of treatment residuals would be available so long as the mining operations continue. Other methods of disposal for treatment residuals would be necessary following mine closure.

e. *Estimated time for design and construction*:

The entire remedy would not be in place for 10 years. A monitoring system would also be needed to ensure that leakage past the barrier wells is not occurring.

f. *Estimated time to reach remediation goals*:

Containment of the plume might be achieved quickly and prevention of exposure to humans and the aquatic species in the Jordan River would also be achieved quickly. The time required to remediate the aquifer could be 150 years or longer.

g. *Estimated costs* (Appendix M, RI/FS)

ESTIMATED COSTS FOR ALTERNATIVE 4

Activity	Capital costs	O+M costs for 30 years	net present value
Monitoring, Institutional Controls, Point of Use Management (Alternatives 1 - 3)	$17.6M	$27.2M	$44.8M
Installation of barrier wells, pump stations and infrastructure	$20.8M	$65.4M	$86.2M
Reverse Osmosis facility	$23.3M	Part of infrastructure O+M	$23.3M
Nanofiltration pretreatment plant after first 10 years	$30.M	$38.4M	$68.4M
Additional barrier wells and upgrades after first 10 years	$21.8M	Part of infrastructure O+M	$21.8M
TOTAL (7% discount)	$86.2M	$103.8M	$217.2M

h. *Use of presumptive remedies or innovative treatment*:

This alternative does not use presumptive remedies. Membrane technology such as nanofiltration is still considered innovative because a number of the operational details and O+M requirements have not yet been fully worked out.

i. *Expected outcome*:

Citizens are protected from exposure to contaminants and the acid plume never reaches the Jordan River. The ground water is cleaned up over time and is returned to beneficial use. Continued monitoring would be necessary to verify barrier well effectiveness.

5 *Alternative 5 - Hydraulic Containment, NF Pretreatment, RO Treatment, Active Pumping of the Core of the Acid Plume and Delivery of the treated water*:

Alternative 5 has two well systems, one for containment of the plume at the plume boundary and another for withdrawal of acidic waters from the core of the plume to begin the remediation of the aquifer. People are prevented from being exposed during the project by point of use management and treated water is provided to communities.

a. *Major elements of Alternative 5*:

- Installation of a barrier well containment system: (The barrier well system collects contaminated waters (primarily sulfate laden) at the leading edge of the plume preventing further migration of the plume. Traditional RO treatment can be used.)

- Installation of a well or wells in the core of the acid plume so that highly acidic waters do not migrate to the barrier wells and remediation of the acid plume can begin quickly: (Modeling suggest that pumping from the core would prevent the acid plume from approaching the barrier well system. Any migration of the acid water beyond the barrier wells could cause severe degradation of ground water quality. With these upgradient core plume wells, the barrier wells become a safety net rather than the primary containment system.)

- Pretreatment of acid waters using nanofiltration: (Waters from the core of the plume are too high in dissolved solids to be treated efficiently with reverse osmosis. Membranes would clog too quickly. Nanofiltration has been shown to work on a pilot scale using acid leachate waters from the site. Operational details need some refinement.)

- Treatment of pretreated core waters and barrier well sulfate waters by reverse osmosis: (Treatment and polishing of waters would be accomplished using traditional RO technology.)

- Treated water is delivered to a municipal water purveyor, as a requirement under the NRD action.

- Pre-mine closure, treatment concentrates are disposed by insertion into Kennecott's tailings line or into Kennecott's mineral processing water circuit.

- Includes all the measures in Alternatives 1, 2, and 3.

b. *Key ARARs*:

In addition to ARARs in Alternative 3, key ARARs include the Utah Drinking Water Regulations, Utah Public Water Supply requirements, the Utah Ground Water Protection Corrective Action program, RCRA, the Utah Pollutant Discharge Elimination Program permit regulations, and Utah Water Rights Laws.

c. *Long term reliability*:

While preventing exposures to the public downgradient, this alternative provides a dual containment system. The acid wells would withdraw waters from the core of the plume. Drawdowns within the aquifer caused by this pumping should theoretically stop all eastward movement of the plume. The barrier wells along the front of Zone A would provide a safety net to stop less concentrated materials from escaping downgradient. The technology has been shown in preliminary pilot tests to work on the plume and, with proper maintenance, the technology will be reliable.

d. *Quantity of untreated waste and treatment residuals*:

At the end of the remedial action, there should be no untreated wastes. If a combined barrier well/acid well pumping rate of 3500 gpm is assumed, treatment residuals could be as high as 1300 gpm over the life of the project. Existing infrastructure for management of treatment residuals would be available so long as the mining operations continue. Other methods of disposal for treatment residuals would be necessary following mine closure. A plan will be developed using current technology as a part of the Remedial Design which can be implemented immediately, with the understanding that a different strategy can be used upon approval by EPA and UDEQ using technology available at the time of mine closure.

e. *Estimated time for design and construction*:

Construction completion is estimated to take 5 years. Design and experimentation with treatment parameters could take 1.5 years of this.

f. *Estimated time to reach remediation goals*:

Containment of the plume could be achieved quickly and prevention of exposure to people in the affected area and the aquatic species in the Jordan River could also be achieved quickly. The time required to remediate the aquifer could be 150 years or longer. Modeling suggests that the original core of the acid plume would be largely removed in the first 30 years. However, withdrawals and treatment would have to continue for a long time as components in the solid phase of the impacted aquifer materials begin to re-dissolve back into the water as the fresh water flows through the contaminated aquifer material. The time it would take to achieve a total cleanup is unknown. Further modeling and monitoring may give insights on progress as the project continues.

g. *Estimated costs*: (Appendix M, RI/FS)

ESTIMATED COSTS FOR ALTERNATIVE 5

Activity	Capital costs	O+M costs for 30 years	net present value
All the measures in Alternatives 1, 2, and 3	$18M	$27M	$45M
Installation of a barrier well containment	$8.98M	$19.23M	$28.11M
Withdrawal from the core of acid plume and Pretreatment of this acid water using NF	$23.1M	$33.9M	$47.0M
Treatment of pretreated acid waters by reverse osmosis	$2.9M	Included in RO costs	$2.9M
Treatment of sulfate waters from barrier sulfate wells by reverse osmosis	$17.5M	$21.3M	$38.8M
Treated water is delivered to a municipal water purveyor	included in treatment	included in treatment	included in treatment

Activity	Capital costs	O+M costs for 30 years	net present value
Concentrates are disposed in Kennecott's tailings line	$4.4M	$21.0M	$25.4M
TOTAL	$74.5M	$122.7M	$197.2M

h. *Use of presumptive remedies or innovative treatment:*

This alternative does not use presumptive remedies. Membrane technology such as nanofiltration is still considered innovative because a number of the operational details and O+M requirements have not yet been fully worked out. Disposal of the treatment residuals into the existing tailings pipeline is also innovative. It takes advantage of the neutralization capacity of the tailings in a 13-mile long pipeline to neutralize the treatment concentrate and precipitate out the metals. Because it takes advantage of existing infrastructure of the mill, it is also very cost effective.

i. *Expected outcome:*

Citizens are protected from exposure to contaminants and the acid plume never reaches the Jordan River. The aquifer is cleaned up over time. Based on modeling predictions, most of the cleanup occurs while the mining operations continue so existing infrastructure can be used. The ground water is returned to beneficial use.

6 *Alternative 6 - Hydraulic Containment, NF Pretreatment,RO Treatment, Active Pumping of the Acid Plume and Lime Treatment of Treatment Residuals*

a. *Major elements of Alternative 6:*

- Same as Alternative 5, except acidic waters are withdrawn from the aquifer, treated with NF and the treatment concentrate is treated with lime. Two waste streams are generated: solid residuals from lime treatment and the water which is not delivered to the public but is used as process waters by Kennecott. The RO plant treats only the waters from the barrier wells, not waters from the core of the plume.

- Standard technology for lime treatment of acid rock drainage used by the mining industry is used instead of more innovative technology such as treatment in the tailings pipeline.

- Treatment residuals from lime treatment of the nanofiltration concentrations are stored in a lined repository located close to the treatment plant.

b. *Key ARARs*:

In addition to ARARs in Alternative 5, key ARARs include the Utah Drinking Water Regulations, the Utah Ground Water Protection Corrective Action program, Utah Water Rights Laws and the Utah Pollutant Discharge Elimination Program permit regulations. Depending on the composition of the lime wastes, RCRA Hazardous Waste regulations are relevant and therefore influence the design of the repository. It would also need to meet the substantive requirements of the Utah Ground Water Protection Program.

c. *Long term reliability*:

While preventing exposures to the public downgradient, this alternative provides a dual containment system. The wells in the core of the acid plume would withdraw highly contaminated ground water. Drawdowns within the aquifer caused by this pumping should theoretically stop all eastward movement of the plume. The barrier wells of the acid plume would provide a safety net to stop less concentrated materials from escaping downgradient. The lime treatment technology is not innovative and has been used with reliability in the mining industry for years. However, it does present a disposal problem for the solid wastes produced by the lime treatment.

d. *Quantity of untreated waste and treatment residuals:*

At the end of the remedial action, there should be no untreated wastes. If a combined barrier well/core well pumping rate of 3500 gpm is assumed, treatment residuals could be as high as 240,000 tons/year.

e. *Estimated time for design and construction*:

Construction completion is estimated to take 5 years. Design and experimentation with treatment parameters could take 1.5 years of this.

f. *Estimated time to reach remediation goals*:

Containment of the plume could be achieved quickly and prevention of exposure to people in the affected area and the aquatic species in the

Jordan River would also be achieved quickly. The time required to remediate the aquifer could be 150 years or longer. Modeling suggests that the original core of the acid plume would be largely removed in the first 30 years. However, withdrawals and treatment would have to continue for a long time as components in the solid phase of the impacted aquifer materials begin to re-dissolve back into the water as clean water flows through the contaminated aquifer material. The time it would take to totally cleanup the ground water and the aquifer materials is unknown.

g. *Estimated costs*

ESTIMATED COSTS FOR ALTERNATIVE 6

Activity	Capital Costs	O+M/30 years	net present value
Alternative 5 (except method for disposal of treatment residuals)	$74.5M	$122.7M	$197.2M
Treatment residuals treated with lime and sludge removal	$13.2M	$149.8M	$163.2M
TOTAL	$87.7M	$272.5M	$360.4M

h. *Use of presumptive remedies and innovative treatment*:

This alternative does not use presumptive remedies. It uses an innovative membrane technology (nanofiltration) treatment for the acid waters.

i. *Expected outcome*:

Citizens are protected from exposure to contaminants and the acid plume never reaches the Jordan River. The aquifer is cleaned up over time. The ground water is returned to beneficial use. The volume of lime required using this approach would be large leading to a great increase of traffic in the area. A regulated retention structure for the sludge would be needed.

7 *Ancillary alternatives for special situations*

a. *Alternatives for NF concentrate disposal following cessation of mining and milling operations in 30 years* (tailings pipeline would no longer have tailings flows). These apply to Alternatives 4 and 5.

- Pump the concentrate to a lined facility on the waste rock dumps for evaporation, disposal of the sludges in the dump or in a lined storage facility.

- Use the former tailings pipeline or another dedicated pipeline to convey concentrate to shallow ponds on the top of the new tailings pond for evaporation. Lining depends on the characteristics of the residuals.

- Same as above, but create solar ponds to create electricity. Electricity could be used to help evaporate water during the winter months. Sludge storage is also necessary.

- Lime treatment and disposal of residuals in an on-site RCRA-like repository.

b. *Alternative for RO concentrate disposal following mine closure in 30 years* (this applies to Alternatives 4, 5 and 6):

- Direct disposal in the Great Salt Lake via a new pipeline and outfall. This depends on the nature of the concentrate and impacts on the Great Salt Lake

- Evaporation ponds

c. *Alternatives for well-head protection*

Because there is a possibility that water level drops might affect municipal and private wells throughout the area, additional alternatives for Well Head Protection were developed. In the case of Alternatives 1, 2, and 3, these might be needed to protect wells from being impacted by contaminated water as the plume moves through. In the case of Alternatives 4, 5, and 6, this is needed to prevent wells from going dry as the acid plume in Zone A is aggressively pumped out of the aquifer. These measures might also be needed if the barrier well system is ineffective in totally containing the plume.

- For the West Jordan municipal well field:
    - Install injection wells between the acid plume and the West Jordan municipal well field. (This requires permission from UDEQ.)
    - Inject sufficient water into aquifer to prevent excessive water level drops near West Jordan well field and prevent acid plume migration in that direction. (This requires permission from UDEQ.)
    - Water would come from uncontaminated sources of water in the nearby mountains.

- If draw downs are the main problem, storage of water in the winter months in above ground tanks instead of reinjection.

- For private wells:
  - Hook up to municipal water.
  - Installation and maintenance of a residential reverse osmosis treatment system if municipal water hook up is impractical.
  - Deepening of the affected well if it is thought that a deeper well would yield sufficient replacement water.
  - Replacement of water using other sources.
  - Underground injection up gradient of affected wells to counterbalance the drops. (This requires permission from UDEQ.)

J. Summary of Comparative Analysis of Alternatives:

The National Contingency Plan (NCP) requires that the various remedial action alternatives be evaluated individually and then compared relative to each other using nine criteria. The nine criteria in the National Contingency Plan and how the alternatives compare are described below:

1. Overall protection of human health and the environment

Overall protection of human health and the environment addresses whether each alternative provides adequate protection of human health and the environment and describes how risks posed through each exposure pathway are eliminated, reduced, or controlled, through treatment, engineering controls, and/or institutional controls.

Alternatives 2, 3, 4, 5, and 6 all protect human health. Alternatives 4, 5, and 6 use institutional controls to limit exposure of humans to the contaminated ground water while the aquifer itself is being restored. In Alternatives 2 and 3, human health is also protected by limiting exposure of the public to the contaminated waters through the use of institutional controls. For these alternatives, institutional controls are the sole mechanism of prevention both short term and long term. Alternative 1 does not protect human health.

Alternatives 4, 5, and 6 protect the environment by preventing migration of the plume. The plume never reaches the Jordan River where exposure to aquatic life could occur.

Alternatives 1, 2, and 3 do nothing to contain the plume or prevent it from reaching the Jordan River. They would not protect the environment.

2. Compliance with Applicable or Relevant and Appropriate Requirements

CERCLA and the NCP require that remedial actions at CERCLA sites at least attain legally applicable or relevant and appropriate Federal and State requirements, standards, criteria, and limitations which are collectively referred to as ARARs, unless such ARARs are waived under conditions outlined by CERCLA.

Applicable requirements are those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations that are promulgated under Federal environmental or State environmental or facility siting laws. These regulations specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those State standards that are identified by a state in a timely manner and that are more stringent than Federal requirements may be applicable. Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations that are promulgated under Federal environmental or State environmental or facility siting laws. These requirements, while not applicable to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site do address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well-suited to the particular site. Only those State standards that are identified in a timely manner and are more stringent than Federal requirements may be relevant and appropriate.

The NCP Criterion of compliance with ARARs addresses whether a remedy will meet all of the applicable or relevant and appropriate requirements of other Federal and State environmental statutes or provides a basis for invoking a waiver.

Alternatives 4, 5, and 6 would comply with ARARs through appropriate designs. Alternatives 1 - 3 would not comply with chemical specific ARARs

3. *Long Term Effectiveness and Permanence*

Long term effectiveness and permanence refers to expected residual risk and the ability of a remedy to maintain reliable protection of human health and the environment over time, once clean-up levels have been met. This criterion includes the consideration of residual risk that will remain onsite following remediation and the adequacy and reliability of controls.

All alternatives, except the no action Alternative 1, provide some degree of long term protection. Alternatives 4, 5, and 6 offer a permanent cleanup of the aquifer allowing eventually the full use of the ground water resource. The Jordan River would be protected by the remedial action preventing the migration of the plume.

Alternatives 2 and 3 can be effective but access to the contaminated ground water by use of water rights and the circumvention of the institutional controls is possible. The Jordan River would not be protected by these two alternatives. Alternative 1 provides no protection at all to either the public or the Jordan River. The plume would continue to migrate, contaminating the aquifer further and causing the cleanup time to increase.

Alternatives 4, 5, and 6 would produce some form of treatment residuals which would require proper handling and maintenance to maintain effectiveness.

4. *Reduction of Toxicity, Mobility, or Volume through Treatment*

Reduction of toxicity, mobility, or volume through treatment refers to the anticipated performance of the treatment technologies that may be included as part of a remedy.

Alternatives 4, 5, and 6 all use treatment technologies that would reduce toxicity, mobility and volume of the contaminated ground water. Although Alternative 3 uses in home treatment technology, the purpose is not treatment of the aquifer itself and does not reduce toxicity, mobility or volume. Alternatives 1 and 2 do not involve any treatment at all and would not reduce toxicity, mobility and volume of the contaminated plume. In fact it is likely that the volume of contaminated ground water would actually increase under Alternatives, 1, 2, and 3.

5. *Short term effectiveness*

Short term effectiveness addresses the period of time needed to implement the remedy and any adverse impacts that may be posed to workers, the community and the environment during construction and operation of the remedy until cleanup levels are achieved.

Alternatives 2, 3, 4, 5 and 6 would be effective in the short term because all of these alternatives depend, in the short term, on limiting exposures to humans via institutional controls. Alternatives 3, 4, 5, and 6 are enhanced by providing alternative sources of water to those whose wells are limited by the controls. Alternative 1 is not effective, short term or long term.

6. *Implementability*

Implementability addresses the technical and administrative feasibility of a remedy from design through construction and operation. Factors such as availability of services and materials, administrative feasibility, and coordination with other governmental agencies are considered.

Implementability at this site is a function of the complexity of the remedy. Alternative 1, the no action alternative is most implementable because no one has to do anything extra. Well owners would have to protect themselves. Alternatives 2 and 3 requires the cooperation of the State Engineer and the local governments in restricting the use of the ground water and/or restricting land use. Alternatives 4, 5, and 6 in addition to the above cooperation, also require cooperation of the State Engineer to give permission to pump at rates effective to contain the contamination even though water levels throughout the area might drop thus affecting other water rights owners. A cooperative municipal water purveyor would also be needed to accept the treated water which is also a requirement of the NRD settlement. Alternative 6, in addition to all the cooperation required above would also require large volumes of lime and produce large volumes of residual wastes. Traffic problems and wear and tear on roads could be the result.

7. *Cost*

The types of costs that are assessed include capital costs, annual operation and maintenance costs and net present value of capital and O+M costs.

Alternatives 1, 2, and 3 are the least costly, with costs ranging from \$26M to \$45M, but none of these do anything to cleanup the aquifer. The active remediation remedies, Alternatives 4, 5, and 6 are more costly (\$197M to \$360M) but will eventually clean up the aquifer. Alternatives 4 and 5 take advantage of existing mining infrastructure resulting in savings in disposal costs of treatment residues pre-mine closure. Alternative 6 is the most expensive but does not have any apparent advantages over Alternative 5. Note that since the RI/FS was completed, the total costs for Alternative 5 have been reduced.

8. *State acceptance*

This includes the state's position and key concerns related to the alternatives and comments on ARARs and proposed use of waivers.

In 1995, the state and Kennecott negotiated a Consent Decree to settle a Natural Resources Damage Claim for damages to the ground water in the Southwest Jordan Valley. The terms of the Consent Decree established a cash payment and a letter of credit based on the estimated cost to contain, remove, and treat the contaminated ground water from the plume (Zones A and B). Kennecott could apply for a rebate against the letter of credit by extracting the contaminated water, treating it to drinking water quality standards and providing it to a purveyor of municipal water for use in the affected area. In December, 1999, Kennecott submitted to the State Trustee a plan for use of the Natural Resources Damage settlement dollars. The plan is a combination of Alternative 5, as defined in this ROD, and an additional treatment of sulfate contaminated ground waters downgradient of the Zone A acid plume. Therefore, the state supports Alternative 5, because this alternative is most consistent with the requirements of the NRD action. The state opposes Alternatives 1, 2, and 3 because they essentially sacrifice the aquifer's future use forever. In a semi-arid climate, sacrificing any future water resource has economic development impacts and presents a continuing threat which will have to be managed in perpetuity. Alternative 4 takes longer than Alternative 5, active cleanup of the Zone A acid plume does not take place in the beginning, the potential for this plume not to be captured by the barrier wells is too risky, and costs more. Alternative 6 costs more than Alternative 5 without any apparent benefit to the aquifer or the citizens of Utah.

9. *Community Acceptance*

This determines which components of the alternatives the community support, have concerns about, or oppose.

The primary vehicle of community participation was the Technical Review Committee composed of technical staff from the local governments in addition to state and federal experts. In these discussions, the Committee favored Alternative 5 over Alternative 4 because pumping of the acid plume was slated to begin right away and the core waters would be removed before they could migrate to the downgradient barrier wells. They also favored use of the mining infrastructure as a way to minimize waste handling problems. They liked the concept of attempting to remove most of the acid plume before mine closure. Alternative 6 was not discussed much because it was more costly without any apparent benefit. Alternatives 1, 2, and 3 were unacceptable to the committee because those alternatives sacrificed any use of the aquifer for generations to come.

Alternative 5 in conjunction with a companion NRD settlement plan was supported by the city councils in West Jordan, South Jordan, Herriman, and Riverton. There was some disagreement on the portion of the NRD settlement plan dealing with which cities were to receive the treated water to the four communities in the affected area. All of the cities wanted more water than the proposal allotted, and a few of the private well owners wanted direct supply of the water at wholesale rates.

During the official public comment period and public hearing, very few citizens commented on the relative merits of the alternatives. Instead, most of the comments were on the potential consequences of the implementation of EPA's and UDEQ's preferred remedy. Alternative 5 would result in drawdowns significant enough to influence a wide area in the western part of the valley. This means that water levels in existing wells could drop to the extent that they would be rendered useless, even if the waters in that well were unaffected by the plume. Few opposed the plan because of this, suggesting instead that a plan to deal with these water level impacts on well owners be formulated as a part of the remedial strategy.

Criteria	Alternative 1 No action	Alternative 2 Institutional Controls	Alternative 3 Point of Use Mgt	Alternative 4 Hydraulic Containment	Alternative 5 Active Pumping	Alternative 6 Active Pumping - lime treatment
Threshold criteria - protection of human health and the environment	Would not protect human health or the environment	Would protect human health, but potentially not the environment	Would protect human health, but potentially not the environment.	Would protect human health and the environment	Would protect human health and the environment	Would protect human health and the environment
Threshold criteria - meet ARARs	Would not meet Utah groundwater cleanup standards in a reasonable time frame (800 + yrs)	Would not meet Utah groundwater cleanup standards in a reasonable time frame (800+ yrs), same as Alt 1.	Would not meet Utah groundwater cleanup standards in reasonable time frame (800+ yrs), same as Alt 1	Would achieve ARARs, but might take 50 -150 years or longer	Would achieve ARARs, but might take greater than 50-150 years, but shorter than Alt 4.	Would achieve ARARs, but might take greater than 50 - 150 years, same as Alt 5, shorter than Alt 4.
Long term effectiveness and permanance	Is not effective at all. - Relies entirely on natural attenuation	Relies heavily on institutional controls for long term protectiveness, essentially in perpetuity, and natural attenuation	Relies heavily on institutional controls for long term protectiveness, essentially in perpetuity and natural attenuation	While relying heavily on institutional controls for long term protection, the plume does not move into new areas and eventually shrinks. Concern that acid plume might get by the barrier.	While relying on institutional controls for long term protection, the plume does not move into new areas and is cleaned up in 50-150 yrs. Acid plume never reaches barrier.	Same as 5
Reduction of TMV through treatment	no treatment, no reduction of TMV, volume actually increases as plume moves	no treatment, no reduction of TMV, volume actually increases as plume moves	no treatment, no reduction of TMV, volume actually increases as plume moves	treatment reduces toxicity, mobility, and volume	treatment reduces toxicity, mobility and volume over a shorter time frame	Same as 5
Short term effectiveness	no action, no problems (but no progress either)	no action, no problems (but no progress either)	no action, no problems (but no progress)	no serious problems during construction -pumping rates and well distances need to be determined to ensure effectiveness	no serious problems during construction-pumping rates and well distances need to be determined to ensure effectiveness	Same as 5

Criteria	Alternative 1 No action	Alternative 2 Institutional Controls	Alternative 3 Point of Use Mgt	Alternative 4 Hydraulic Containment	Alternative 5 Active Pumping	Alternative 6 Active Pumping - lime treatment
Implement-ability	no action, no problems (but no protection and no progress)	no engineering action but requires the cooperation of the State Engineer and local governments to control well use	no action, no problems with implementation. Does require aid of state engineer, and local water suppliers	technology available, few problems encountered	technology available, few problems encountered	technology available, few problems encountered, except disposal of sludges produced by lime treatment would require lots of land (and lime supplies could get scarce).
Cost	Low	Low	Low	High	High, but 15% less than Alternative 4	Very High
State acceptance	unacceptable	unacceptable	unacceptable	slower than other active remediation plans, therefore unacceptable	state preference	waste disposal problems
Community acceptance	unacceptable	unacceptable	unacceptable	no comment	communities support this plan, coupled with companion NRD plan	no comment

K. Principal Threat Waste:

The principal threat waste is the source of the acid plume containing high metal and sulfate concentrations. In this case, the sources of the acid plume have been addressed in previous actions. However, the acid plume itself is not much different in composition as the original sources. Alternatives 1, 2, and 3 do not address the remnants of the principal threats in the aquifer itself. Human exposure to the waste is prevented by institutional controls essentially in perpetuity. Alternatives 4, 5, and 6 address the remnants of the principal threats in the aquifer by pumping the acid plume from the aquifer, treating the water, and providing the water to municipalities for beneficial use.

L. Selected Remedy

EPA and UDEQ have selected Alternative 5 as the remedy for addressing the acid plume at Operable Unit 2 of the Kennecott South Zone site.

1. Summary of the Rationale for the Selected Remedy

EPA and UDEQ selected Alternative 5 for the following reasons.

a. EPA and UDEQ preferred active remediation of the plume in Zone A. It was unacceptable to allow the plume to continue to move downgradient polluting more and more ground water as it did so. Containment was a minimum requirement to prevent a major municipal well field from being impacted and to prevent a potential impact on the Jordan River. The active remediation alternatives were Alternatives 4, 5, and 6. All others were eliminated from further consideration as not protective and failing to meet remedial goals.

b. Of the active remediation alternatives, Alternatives 4, 5, and 6, Alternatives 5 and 6 were preferred relative to Alternative 4 because withdrawals of the acid plume were slated to begin right away, 10 years ahead of Alternative 4. This would mean that the aquifer has the potential to be remediated faster in Alternatives 5 and 6. Pilot testing would be required for Alternatives 4, 5, and 6 to prove operation status and sustainability. Alternative 4 also relies on a single barrier well system to contain the plume. The consequences of the acid plume escaping capture of the barrier wells and migrating farther could be extreme.

c. Of the fastest active remediation alternatives, Alternatives 5 and 6, Alternative 5 was preferred because its costs were less with the same benefits to the aquifer. Alternative 5 had the added benefit of using existing waste handling infrastructure of the mining company so long as the mining operations continued. The waste handling problems associated with Alternative 6, although traditional, would have implementability problems requiring transportation of large quantities of lime and treatment sludges. Finally, Alternative 5 fits best with a plan to settle the NRD issues at the site. Similar treatment technologies are proposed for use in both the CERCLA and NRD plans and the systems can be integrated at key spots.

2. Description of the selected remedy

- Operations and maintenance of surface source controls (already implemented under provisions of a state Ground Water Protection Permit).

- Integration and use of Institutional Controls, upon approval by the State Engineer while restoration is ongoing:
  Institutional controls include, but are not limited to, well drilling moratorium by the Utah State Engineer, pumping limits placed on existing wells by the Utah State Engineer, purchase (or exchange) of land, purchase (or exchange) of water rights, municipal zoning and land use regulations. Other options are available to the State Engineer. The State Engineer reviews impacts to the water rights owners and public comments.

- Point of Use Management for private well owners while restoration is ongoing:
  Point of Use Management includes, but is not limited to, providing replacement water to private well owners by hooking them up to municipal culinary systems, the provision of in-home treatment units (e. g., reverse osmosis units) when the household is beyond the municipal service area, the provision of bottled water, extension of wells into uncontaminated portions of the aquifer, replacement of wells.

- Development of a plan to deal with consequences of water level drops caused by pumping of the acid plume:
  The agencies will request that, as a part of RD/RA, the PRP devise a method to mitigate the impact of drawdowns on private and municipal wells located in and near the affected area. This plan could include the following actions, performed on a case-by-case basis: Drilling of new and deeper wells, installing well completions at deeper depths, alternate water sources, purchase or exchange of water rights, well abandonment and compensation.

- Installation of a barrier well containment system at the leading edge of the acid plume (where sulfate concentrations are less than 1500 ppm in the projected migration pathway of the plume movement)
  The performance standard for this system requires that no waters

exceeding state and federal drinking water standards for metals or exceeding 1500 ppm sulfate shall migrate off Kennecott property (as of December 13, 2000) past the barrier wells.

- Installation of a well or wells in the core of the acid plume: (There are already two wells which have been installed in core area for pilot testing purposes.)

- Pretreatment of acid water using nanofiltration.

- Treatment of pretreated acid waters by a reverse osmosis plant.

- Treatment of the waters from the barrier wells by a reverse osmosis plant.

- Treated water is delivered to a municipal water purveyor (as required for a rebate as stated in the Natural Resources Damage Settlement plan and approved by the State Trustee).

- Installation and maintenance of a monitoring system to track the movement of the plume, the progress of active remediation, and measure the progress of natural attenuation for the sulfate contamination within the Zone A plume and downgradient of the barrier wells. The goal of the natural attenuation is to achieve the State's primary drinking water standard of 500 ppm.

- Prior to mine closure, the concentrates from NF plant and RO plant are disposed in Kennecott's tailings pipeline. The tailings pipeline serves as a 13 mile linear treatment system. Acids would be neutralized and metals would precipitate into the tailings slurry. Metals are stored along with tailings in the Magna Tailings Impoundment, newly expanded and renovated.

- Following cessation of nearby mining and milling operations, the NF and RO concentrates shall be disposed in a facility appropriate to the types of wastes then remaining in the concentrate. None of the specific requirements mentioned in the description of alternatives will be chosen at this time. A disposal method which could be implemented quickly following mine closure must be included as a part of RD/RA. In 30 years, it is anticipated that other technologies may be available to handle residuals from the treatment plants. Closure of the mine may require infrastructure and O+M which could be used also for the concentrates, the chemistry of the ground water could be significantly less concentrated than today, and more will be known about the nature of any proposed discharge to the Great Salt Lake and the potential effects thereof. The Agencies also acknowledge the possibility of a completely different option for addressing the concentrates upon mine closure. EPA and UDEQ would then encourage the submittal of a new proposal that takes into consideration changed circumstances and new technology to more effectively address the concentrates.

- Should the plume begin to impact the West Jordan Municipal Well Field (either through increased loadings or water level drops), a reinjection program may be considered.

3. Summary of the Estimated Remedy Costs

The information in this cost estimate summary table is based on the best available information regarding the anticipated scope of the remedial action. Changes in the cost elements are likely to occur as a result of new information and data collected during the engineering and design of the remedy. Major changes may be documented in the form of a memorandum in the Administrative Record file, an Explanation of Significant Differences, or a Record of Decision Amendment. This is an order-of-magnitude engineering cost estimate that is expected to be within +50% to -30% of the actual project cost. Since the RI/FS was submitted, there have been additional cost estimates which are lower than those presented here. This version is verbatim from the RI/FS.

PROJECT COST ESTIMATE
CAPITAL COSTS
(From Appendix M, RI/FS Report, 1998①)

ACTIVITY	Quantity Unit	Unit Cost	Total Cost
Source controls			already constructed
Institutional controls			
Water rights and land use restrictions	1 lot	$16,000,000	$16,000,000
Point of use management			
Municipal Connections	35,000 Linear ft	$25	$875,000
Household Treatment Units	400	$1,500	$600,000
Draw down impacts (potential)			
Private well owners	25 wells with 20-40 ft drops, 15 wells with 40-100 ft drops, 4 wells with >100 ft drops	case by case basis	not estimated

ACTIVITY	Quantity Unit	Unit Cost	Total Cost
Municipal wells	2 wells with 20-40 ft drops, 4 wells with >100 ft drops	case by case basis	not estimated
Reinjection program	unknown	case by case basis	not estimated
Barrier Well extraction and RO treatment			
Wells (C' steel)	10,000 Linear ft	$260	$2,600,000
Well Pump Stations	6	$425,000	$2,550,000
Booster Pump Stations	1	$550,000	$ 550,000
Power substations	3	$150,000	$ 450,000
Reverse Osmosis Facility	2,000 gpm	$3.20/gal per day	$9,216,000
6" - 12" dia. C' steel pipelines	20,000 Linear ft	$85	$1,700,000
8" concentrate C' steel pipeline	500 Linear ft	$70	$ 35,000
Power transmission lines	20,000 Linear ft	$45	$ 900,000
Acid plume (core waters) extraction to Nanofiltration pretreatment and Reverse Osmosis Treatment			
Wells (stainless steel)	5000 Linear ft	$350	$1,750,000
Well Pump Station	5	$500,000	$2,500,000
Booster Pump Station	1	$600,000	$ 600,000
Power substations	2	$150,000	$ 300,000
6" - 12" dia pipelines (stainless steel)	10,000 Linear ft	$140	$1,400,000
Power transmission lines	10,000 Linear ft	$45	$ 450,000
Nanofiltration facility	1,500 gpm (this flow depends on remedial design)	$4.10/gal.day	$ 8,856,000

ACTIVITY	Quantity Unit	Unit Cost	Total Cost
Modify Reverse Osmosis Plant above to increase the flow to 2,750 gpm	1 lot	$2,000,000	$2,000,000
Upgrade existing lime treatment plant at concentrator and head of tailings line (750 gpm)	1 lot	$3,000,000	$3,000,000
New disposal infrastructure for use following mine closure			not estimated
Sub Total			$56,302,000
EPCM	20% construct, 1% IC, POU		$ 8,106,000
Contingency	25% construct, 2% IC, POU		$12,327,000
TOTAL			$76,735,000

① costs were estimated in 1998 and were not adjusted for inflation

ESTIMATED ANNUAL PROJECT COSTS
OPERATIONS AND MAINTENANCE
(From Appendix M, RI/FS Report, 1998)

Activity	Quantity unit	Unit Cost	total
Monitoring			
Personnel and equipment	2 technicians	$50,000	$100,000
Analytical services	700 analyses	$500	$350,000
Annual report preparation	1 lot	$20,000	$20,000
Source Control Operations and Maintenance	1% of construction cost	$127,000,000	$1,270,000
Institutional Controls	none	none	none
Point of Use Management			
Maintenance of household RO units	10% of capital cost	$600,000	$60,000

Activity	Quantity unit	Unit Cost	total
Barrier Well extraction plus RO treatment			
Power for pumping	3,609,000 kWh	$0.035	$126,000
Maintenance	5% of construction cost	$18,001,000	$900,000
RO System	2000 gpm (product flow rate)	$0.84	$883,000
Operations Labor	5 persons	$50,000	$250,000
Acid extraction to Nanofiltration and RO treatment			
Power for pumping	3,003,000 kWh	$0.035	$105,000
Maintenance	5% of construction cost	$20,856,000	$1,043,000
Operations Labor	5 persons	$50,000	$250,000
NF system	1,500 gpm (product flow rate, depends on design)	$1.26	$993,000
Lime	750 gpm at 0.1 lb per gal = 19,710 tons	$75	$1,478,000
Subtotal			$7,828,000
EPCM	1% Source Cont, POU, 5% treatment		$ 318,600
Contingency	5% Source Cont, POU, 25% treatment		$1,673,000
TOTAL			$9,819,600